Essays on Credit Markets and Business Cycles

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Jelena Živanović, MSc

Präsidentin der Humboldt-Universität zu Berlin:
Prof. Dr.-Ing. Dr. Sabine Kunst
Dekan der Wirtschaftswissenschaftlichen Fakultät:
Prof. Dr. Christian D. Schade

Gutachter: 1. Prof. Lutz Weinke, Ph.D.
2. Prof. Dr. Frank Heinemann

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Abstract

This thesis examines the role of corporate debt financing for the real economy. First, I study the conditional dynamics of the external finance premium using US data and find that the premium is countercyclical following supply and monetary policy shocks. Second, I analyze to which extent bank and bond financing affect the transmission of economic shocks in the context of a DSGE model. To the extent that large firms predominantly use capital market finance, whereas small firms rely on bank loans, the model predicts that the composition of corporate debt is relevant for the propagation of shocks. Contractionary monetary policy and financial shocks impair the ability of leveraged banks to provide loans, which adversely affects small firms. Bond financing dependent firms can nevertheless issue bonds in times of rising bond finance premia. These firms do not reduce their investments as strongly as bank financing dependent firms. As a consequence, the economy that relies only on bank credit is affected more by shocks than the economy with bank and bond finance. Finally, the model is used to evaluate the optimal mix of conventional, unconventional and macroprudential policies for segmented credit markets. I find that the optimal policy mix attains the highest welfare gains following financial shocks.

Zusammenfassung

Diese Arbeit befasst sich mit der Rolle der Unternehmenskreditfinanzierung für die Realwirtschaft. Im ersten Teil untersuche ich die Entwicklung der externen Finanzierungsprämien in den USA in Folge von ökonomischen Schocks und finde, dass die Prämie antizyklisch auf Angebots- und monetäre Schocks reagiert. Im zweiten Teil analysiere ich mit Hilfe eines DSGE-Modells, wie die Zusammenfassung aus Bankkreditfinanzierung und Anleihenfinanzierung die Transmission von ökonomischen Schocks beeinflusst. Angenommen, dass große Unternehmen größtenteils Anleihenmärkte verwenden und kleine Unternehmen auf Bankkredite angewiesen sind, zeigt das Modell, dass die Zusammensetzung des Unternehmenskreditfinanzierung relevant für die Verbreitung von Schocks ist. Negative monetäre Schocks und Finanzschocks beeinträchtigen die Kreditvergabe von fragilen Banken, die in Folge die Bankkredite an kleine Unternehmen kürzen. Unternehmen, die auf Anleihenfinanzierung zurückgreifen können, können sich in Zeiten steigender Prämien über Unternehmensanleihen refinanzieren. Daher reduzieren diese Unternehmen nicht in so starken Ausmaß ihre Investitionen wie kleine Firmen. Als Folge davon, ist eine Volkswirtschaft, die nur auf Bankkredite angewiesen ist, stärker von Schocks betroffen als eine Volkswirtschaft mit sowohl Bank- als auch Anleihenfinanzierung. Abschließend wird das Modell verwendet, um eine Kombination konventioneller und unkoventioneller Geldpolitik sowie makroprudentieller

Politik in einer Ökonomie mit segmentierten Kreditmärkten zu evaluieren. Es wird gezeigt, dass der optimale Politikmix die höchsten Wohlfahrtsgewinne in Folge von Finanzschocks erreicht.

To my parents and my brother

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

The Great Recession of 2007-2009 showed how a severe financial crisis can have overwhelming effects on the real economy, causing a deep contraction of output all around the world. It also shaped macroeconomics, by drawing the close attention of researchers and policy makers to the center of the crisis, the financial sector. In the aftermath of the Great Recession, numerous theoretical and empirical frameworks have been developed to analyze the role of financial markets for the real economy. In empirical work, the effects of shocks originating in the financial sector have been quantified.[1] In theoretical work, dynamic stochastic general equilibrium (DSGE) models now feature financial frictions, that amplify the propagation of economic shocks on the real economy in order to mimic the financial crisis.[2]. Regarding policy analysis, different policy measures, including conventional monetary policy, unconventional policy and macroprudential policy, have been proposed to mitigate the effects of financial shocks. An ongoing research in macroeconomics tries to understand the interactions between the real economy and the financial sector, as well as optimal policy response to changes in financial conditions. The purpose of this thesis is to expand the ongoing research on financial frictions, financial shocks and credit market factors.

Within the paradigm by Modigliani and Miller (1958) on the irrelevance of the financial structure, the real economy is insulated from conditions in financial markets. As argued by Bernanke et al. (1999), this irrelevance proposition ceases to hold if financial markets feature frictions such as asymmetric information and moral hazard problems. Hence, many DSGE models now incorporate financial frictions in order to understand the role of financial markets in the propagation of business cycle fluctuations. Despite extensive research on financial markets and financial frictions, there is still no workhorse model with financial frictions that is supported by data. This dissertation tries to shed some light on which financial frictions are

[1] See, e.g., Gilchrist and Zakrajšek (2012); Meeks (2012); Furlanetto et al. (2014) among others.
[2] See, e.g., Gertler and Karadi (2011); Christiano et al. (2014); Brzoza-Brzezina et al. (2013); Gerali et al. (2010), to name a few.

relevant and should, hence, be embedded in theoretical models.

Credit slump is often at the center of financial crisis - credit conditions worsen, firms go bankrupt in the absence of financing opportunities or due to costly external finance, and banks renege on the role of financial intermediation. Unavailability of credit can hinder firms from undertaking investment projects and can enhance a contraction of output at times of financial crisis. Providing stylized facts on the US corporate credit market during the Great Recession, Adrian et al. (2012) and Bekaert et al. (2013) document a surge in corporate bonds issuance and a decline in bank lending, and suggest that a change in the composition of corporate credit is an important dimension of the latest crisis. Motivated by the empirical evidence, a DSGE model is developed to understand to what extent cyclical variations in corporate debt affect the transmission of shocks.

In recent years central banks around the world have tried to tackle conditions in the afflicted asset markets using both conventional and unconventional policy measures. Addressing the expansion of central banks' balance sheets, Cúrdia and Woodford (2011) showed that the optimal policy should be tailored to the degree of a disruption in the relevant financial market as well as to a type of financial disturbance. To challenge this result, I use my model economy with two credit market segments for a welfare analysis of conventional and unconventional central bank's policies.

In the second chapter of this thesis, I conduct an empirical analysis of the external finance premium (EFP) using the US data, and find that the countercyclical EFP is consistent with an important subset of financial frictions models. In the third chapter, based on the empirical evidence, I propose a DSGE model to analyze the role of bank and non-bank corporate debt for business cycle fluctuations. I argue that the change in corporate debt composition attenuates the effects of shocks on investment and output. In the fourth chapter, I analyze optimal central bank's policy setup within the context of the same model and show that the benefits from the optimal policy response are large in the presence of economy-wide shocks. However, this result is partly reversed in the presence of sector-specific financial shocks.

The second chapter, "A structural empirical analysis of the external finance premium", analyzes the conditional dynamics of the external finance premium (EFP) using a structural vector autoregression (SVAR) model. I find a common denominator from DSGE models with financial frictions in order to impose a set of signs restrictions that exclusively identify macroeconomic and financial shocks. My results indicate that the corporate credit spread, a proxy for the EFP, is countercyclical conditional on the realization of aggregate supply and monetary policy shocks. Then, I confront my empirical evidence with the predictions from financial DSGE models to answer the following questions: What is the relevant financial friction? Which modeling framework is favored by the data? The answer is that various prominent financial DSGE models are consistent with my empirical evidence. Financial DSGE models featuring different financial frictions (e.g., moral hazard, costly state verification, collateral constraints) generate a countercyclical EFP following supply shocks and monetary policy shocks. This empirical evidence motivates modeling choices made in the following chapter.

In the third chapter, "Corporate debt composition and business cycles", I develop a theoretical framework to analyze the role of bank and bond finance in the propagation of macroeconomic and financial shocks. In particular, I incorporate relevant financial frictions from the first chapter into a medium-scale DSGE model, where leveraged banks, modeled along the lines of Gertler and Karadi (2011), supply loans to small firms and mutual funds, specified as in Bernanke et al. (1999), provide bond financing to large firms. Within this setup, I ask the following questions: To what extent does the corporate debt composition (bank versus bond finance) affect the transmission of macroeconomic and financial shocks? Is a bank-dependent economy more adversely inflicted by shocks? To explain the role of the corporate debt composition, I compare an economy consisting only of a banking sector with an economy featuring bond and bank markets. I document attenuated effects of contractionary monetary and financial shocks on investments in the economy with the heterogeneous corporate debt structure. The reason is to be found in the workings of the bank lending channel and the capital market channel. The bank lending channel highlights the role of loan supply restrictions for small firms, which in turn strongly reduce their investments. The capital market finance channel signals the availability of external debt for large firms in exchange for higher bond finance premia. As unconstrained mutual funds provide financing to large firms, these firms do not reduce their investments as strongly as small firms. As a consequence, the economy that relies only on bank finance is affected more by monetary and financial shocks than the economy with bank and bond finance. The model presents one theoretical mechanism that explains why financial shocks have stronger short-term real effects in Europe than in the US (as reported by Gambetti and Musso, 2017).

The fourth chapter,"An optimal policy mix for segmented credit markets", provides a normative analysis of central bank's policies. In recent years central bank policy instruments have expanded to include unconventional policy measures to address disrupted credit markets (e.g., during the Great Recession) and macroprudential frameworks to tackle future risks emanating from these markets. As argued by Cúrdia and Woodford (2011), central banks' policies should be tailored to address severely disrupted financial markets. How should monetary policy be conducted in an environment with two credit market segments? Using the model presented in the third chapter, I evaluate the welfare performance of conventional monetary policy rules and a policy combination of conventional, unconventional and macroprudential policies. How important is it that the central bank conducts the optimal policy? Obviously, it is very important, in the case of economy-wide financial shocks. Along the lines of the literature featuring only one financial market (see, e.g., Cúrdia and Woodford, 2010; Gertler et al., 2012; Bailliu et al., 2015) the finding of large benefits of non-standard policies continues to hold in the model with segmented credit markets. Within the context of my model, by addressing a specific credit market segment with the policy tool at disposal, the central bank achieves a more desirable macroeconomic outcome than it would by using only conventional monetary policy. The stabilization effects arise from intervening in the more disrupted credit market and combating negative effects of shocks in the market where they arise. My further contribution to the literature concerns welfare implications of sectoral financial shocks. How large are the mistakes that a policy maker commits if she does not identify the source of a sectoral financial shock? Surprisingly, the mistakes are small in comparison to the optimal policy response, if the policy maker assumes that both credit markets are affected by financial shocks and conducts her optimal policy accordingly. Is the source of sectoral financial shocks important for the optimal policy? Counterintuitively, within my framework, there are also shocks that leave the central bank helpless.

The thesis attempts to improve the understanding of credit markets using state-of-the art macroeconomic models along three major dimensions: First, my empirical evidence helps discriminate among financial friction models. Second, the theoretical framework offers one explanation for why the composition of corporate debt is relevant for economic fluctuations. Third, optimal policy decisions are evaluated for the economy featuring two segmented credit markets.

Chapter 2

A structural empirical analysis of the external finance premium

Abstract

I use an SVAR with sign restrictions to provide conditional evidence on the behavior of the US external finance premium (EFP). Importantly, the SVAR is identified in a theory-consistent manner. The results indicate that the corporate credit spread, a proxy for the EFP, reacts countercyclically to supply and monetary policy shocks. I confront my empirical evidence with the predictions from financial DSGE models with respect to the finance premium. Therefore, the results add empirical discipline to the modeling of financial frictions. Major financial frictions models (e.g., Bernanke et al., 1999; Gertler and Karadi, 2011) generate transmission mechanisms that are consistent with the data.

Keywords: External finance premium, business cycles, structural vector autoregression, sign restrictions
JEL Classification: E32, E44

2.1 Introduction

In recent years numerous theoretical frameworks have been developed to analyze the role of financial markets for the real economy. Such models use financial frictions to generate an endogenous external finance premium (henceforth, EFP), i.e., a wedge between the external and internal costs of financing. Most financial DSGE models emphasize the role of the premium in propagating shocks (see, e.g., Bernanke et al., 1999; DeGraeve, 2008; Cúrdia and Woodford, 2011; Kaihatsu and Kurozumi, 2014, among others), however, they come to different results regarding the cyclicality of the premium. In contrast to the prominent role of the EFP in theoretical models, little empirical evidence on EFP has been provided.[1] This paper fills the gap in the empirical literature by analyzing the conditional dynamics of the US external finance premium in an SVAR with sign restrictions.

My results indicate that a countercyclical EFP arises in response to supply and monetary policy shocks. The results are robust to the use of different proxies for the EFP, i.e., different corporate credit spreads. The empirical evidence on the EFP can be used as a guidance for gaining insights about which theoretical models are in line with the data. The findings indicate that various types of financial frictions (costly state verification framework à la Townsend (1979), moral hazard or collateral constraints) generate transmission mechanisms that are consistent with my estimated dynamic consequences of shocks with respect to the EFP. In a nutshell, the propagation mechanism arising in these financial DSGE models is the following: A negative comovement between the EFP and output conditional on technology shocks arises because inflation reacts countercyclically, which leads to a countercyclical development of leverage and the EFP. An unexpected monetary tightening decreases aggregate demand, which together with the decline in the price of capital and the higher value of debt, results in an increase in the EFP (making it countercyclical).

The role of credit spread movements in the US business cycles has been addressed in the recent literature.[2] Taking credit spreads as a measure of the EFP, my analysis extends the literature along two dimensions: First, financial shocks (i.e., shocks to the EFP) are identified and disentangled from macroeconomic shocks (aggregate supply and monetary policy shocks) in a theory-consistent manner. My structural approach is based on the common denominator from various DSGE frameworks modeling financial frictions. This means that a minimal set of sign restrictions shared by the models is used to exactly identify each shock. The studies of Gilchrist and Zakrajšek (2012) and Meeks (2012) focus solely on credit market disturbances. Second, theoretical models do not provide a consensus on how the finance premium should respond to macroeconomic shocks and, therefore, my conditional empirical analysis is informative in this respect, i.e., it aims at identifying an empirically relevant financial frictions model for studying interactions between the real and financial side of the economy. In doing so, I add some empirical discipline on the modeling of financial frictions.

The novelty of the analysis is the focus on the dynamics of the EFP conditional

[1] Unconditionally, proxies of the premium are countercyclical indicators. Empirical studies by Gilchrist and Zakrajšek (2012) and Hristov et al. (2012), among others, document a rise in the finance premium following negative financial shocks.

[2] See, e.g., Gilchrist and Zakrajšek (2012); Meeks (2012); Gertler and Lown (2000) among others. The identified credit spread shocks have the nature of credit supply shock, i.e., credit volume and the price of credit move in the opposite directions (see Gambetti and Musso, 2017; Hristov et al., 2012). For efficiency reasons, my small-scale SVAR does not include a loan rate and concentrates instead on the corporate borrowing costs relative to a certain reference rate.

on identified structural shocks. To the best of my knowledge, the only paper exploring the behavior of the EFP in response to multiple shocks is the work by Furlanetto et al. (2014). Despite differences in the identification,[3] my results confirm the findings by Furlanetto et al. (2014) regarding the countercyclicality of the EFP conditional on supply shocks. However, along the lines of monetary policy shocks, my results differ from theirs. Unlike the authors, I use the conditional dynamics of the EFP to infer which financial frictions models match the empirical evidence. In this respect, my results are good news for those DSGE models (see, e.g., Gertler and Karadi, 2011; DeGraeve, 2008; Gerali et al., 2010) which generate a rise in the premium conditional on supply and monetary policy shocks. However, frameworks with nominal optimal debt contracts (e.g., Christensen and Dib, 2008) or heterogeneous financing needs by (e.g., Cúrdia and Woodford, 2010) imply transmission mechanisms that are not favored by my empirical evidence.

The remainder of the paper is organized along the following lines. Section 2 discusses the model specification. Section 3 presents the main results and the robustness analysis. Section 4 concludes.

2.2 Model specification

2.2.1 Methodology and data

A VAR model is given by:

$$x_t = A + B_{(i)} x_{t-i} + u_t, \tag{2.1}$$

where x_t is a $N \times 1$ vector containing N endogenous variables, A is $N \times 1$ vector of constants, $B_{(i)}$ for $i = 1, \dots M$ represents $N \times N$ coefficient matrices for lag i, M is the number of lags and u_t is the $N \times 1$ one-step ahead prediction error with a variance-covariance matrix of size $N \times N$. The SVAR methodology with sign restrictions follows the work by Uhlig (2005) and Rubio-Ramírez et al. (2010) and is summarized in appendix A.

In my structural model specification, vector x_t contains six variables:

$$x_t = [y_t, p_t, r_t, cr_t, EFP_t, q_t], \tag{2.2}$$

whereby, y_t represents the real GDP in period t, p_t the GDP deflator, r_t the federal funds rate, cr_t the credit volume, EFP_t the external finance premium and q_t

[3] Whereas asset price shocks of Furlanetto et al. (2014) cause investment and stock market booms with a positive price reaction (i.e., demand-side financial shocks) adverse credit spread shocks in my identification cause both a credit crunch and a stock market bust with an ambiguous effect on inflation. Since I do not specify the price reaction a priori, the financial shock can be either a demand or supply-side disturbance in my SVAR.

the price of capital. The VAR specification includes a constant and three lags of endogenous variables in the baseline model.[4] The model is estimated for the US with data in logs from 1973Q1-2010Q3. The federal funds rate and the EFP are reported in levels.

The set of financial indicators is supposed to be representative for stock and credit markets. The S&P500 stock market index is used as a proxy for the price of capital (c.f., Bassett et al., 2014; Christiano et al., 2010, 2014). The price of capital is one of the major determinants of net worth of firms in theoretical models, which is empirically identified with the value of equity, i.e., the stock market index. Following Christiano et al. (2014), the price of capital and the value of equity are the identical concepts in the data. The empirical counterpart for total lending to firms in theoretical models is represented by the amount of credit to the corporate nonfinancial sector.

The external finance premium is the key variable in the process of credit intermediation. It is not observable[5] and therefore it is hard to measure. As argued by Gertler and Lown (2000), it would be useful to have data on the individual bank loan rates from US firms, since this would allow researchers to obtain a good measure of external financing costs. Unfortunately, this data is not available. The available bank rate represents a rate posted by banks, i.e., it is not determined by the market. For these reasons, most researchers gather the market data from corporate bond yields to infer a proxy for the premium. Credit spreads are commonly used as measures of the EFP: the spread between yields on BAA- and AAA-rated corporate bonds (i.e., the BAA-AAA spread), the spread between yields on BAA-rated corporate bonds and 10-year-Treasury yields (i.e., the BAA-10Tr spread), the high-yield spread, to name a few. One of prominent proxies for the premium is the spread index developed by Gilchrist and Zakrajšek (2012) (henceforth, GZ credit spread). By matching individual corporate bond yields with their reference interest rate of the appropriate maturity, the authors provide a good measure of external financing costs for corporate firms. In particular, the average credit spread is calculated using senior unsecured bonds issued by nonfinancial firms of credit quality ranging from "D" to "triple A". For my main analysis, I employ the GZ credit spread as a measure of the EFP for the following reasons: First, the advantages of using this spread over the BAA-AAA spread is that it accounts for the maturity horizon of the microdata precisely.[6] It is well known that the BAA and AAA corporate bond indexes, together with other aggregate credit spread indexes, contain bond

[4]The lag length is chosen based on the Akaike information criterion.

[5]The unobservability of the external finance premium, as argued by DeGraeve (2008), is the most problematic aspect for researchers. Following DeGraeve (2008), I employ various credit spreads as proxies for the EFP.

[6]For the reference rate for the spread, Gilchrist and Zakrajšek (2012) employ a synthetic Treasury security with the same cash flow characteristics as the underlying corporate bond and, hence, both yields have the same maturities.

yields of different maturities and, therefore, they suffer from "duration mismatch" (see Gilchrist and Zakrajšek, 2012). Second, the GZ-credit spread encompasses a wide spectrum of firms with different credit quality, which implies that it is a broad indicator of financial conditions. Other measures concentrate on firms with good credit standing (e.g., BAA-AAA spread) or bad credit quality (e.g., high yield-spread) and, hence, they reflect only one narrow market segment for corporate borrowing. Third, according to Gilchrist and Zakrajšek (2012), the GZ credit spread captures the compensation for defaults of individual firms and exposure to corporate credit risk and, hence, it reflects the premium for external costs of financing. The drawback of the GZ credit spread is that it is based on the universe of firms that have access to unsecured corporate bonds. The development of the spread is presented in figure A.1 in apppendix A.

The GZ credit spread, termed also the corporate credit spread, is a proxy for the EFP, however, I will use all three expressions interchangeably. As a part of the robustness exercise, I employ different measures of the EFP. I use standard corporate credit spreads, such as the BAA-AAA spread, the BAA-10Tr spread and a measure of external bond premium (EBP). Gilchrist and Zakrajšek (2012) estimate the EBP from their data on individual bond yields and firm characteristics. This measure reflects changes in the pricing of default risk and it is a component of the GZ credit spread.

2.2.2 Identification strategy

Table 2.1 summarizes a minimal set of sign restrictions used to identify structural shocks.[7] The sign restrictions are based on the dynamic consequences of shocks in financial New Keynesian (NK) models. The advantage of using a parsimonious SVAR model is that identification restrictions are consistent with predictions from a wide range of financial DSGE models.

The sign restrictions used to identify aggregate supply and monetary policy shocks follow common practice (c.f., Canova and Nicoló, 2002; Peersman and Straub, 2006). As standard NK models, financial NK models show a consensus regarding macroeconomic shocks: i) Aggregate supply shocks move output in one direction and inflation and the nominal interest rate in the opposite direction. ii) An unexpected increase in the nominal interest rate results in a decrease in output and inflation. Similar to Uhlig (2005), I impose sign restrictions for two quarters to

[7]A widespread alternative methodology is a recursive VAR, which uses the Cholesky ordering. However, the Choleski decomposition is not supported by the DSGE theory, as argued by Bjørnland and Leitemo (2009) and Furlanetto et al. (2014). Using DSGE models to achieve a theory-consistent identification, I apply the SVAR methodology with sign restrictions to analyze structural shocks.

Table 2.1: Sign restrictions in the baseline model

	Supply	Monetary	Financial
Real GDP	-	-	-
GDP deflator	+	-	NA
Nominal interest rate	+	+	-
Credit	NA	NA	-
EFP	NA	NA	+
Stock prices	NA	NA	-

Notes: A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; "NA" indicates that the impact impulse response can be positive, negative or zero and, therefore, no sign is assigned. All the shocks represent adverse disturbances.

identify monetary policy shocks.[8] In the case of the other shocks, the restrictions are imposed on impact. Examples of aggregate supply shocks include technology shocks and labor supply shocks. The sign restrictions imposed to identify financial shocks are discussed separately.

Table 2.2: Sign restrictions on the EFP

	Financial friction	Supply	Monetary	Financial
Bernanke et al. (1999)	CSV	+	+	+
Carlstrom et al. (2014)	CSV	NA	-	+
Christensen and Dib (2008)	CSV	-	+	NA
Christiano et al. (2010)	CSV	$-/+^*$	+	+
Cúrdia and Woodford (2010)	heterogeneity	-	-/0	+
DeGraeve (2008)	CSV	+	+	NA
Gerali et al. (2010)	collateral constraints	+	-	+
Gertler and Karadi (2011)	moral hazard	+	+	+
Meh and Moran (2010)	moral hazard	-	+	+
Brzoza-Brzezina et al. (2013)	CSV	-	+	+
Brzoza-Brzezina et al. (2013)	collateral constraints	0	0	+

Notes: A "+" indicates that a rise in the EFP on impact, i.e., it is countercyclical; a "-" indicates a fall in the EFP on impact, i.e., it is procyclical; a "0" indicates a zero-response of the EFP on impact; "NA" indicates that the model does not consider a specific shock. *Christiano et al. (2010) report that the premium increases in the model without the Fisher effect. If the EFP is not present in a particular model as such, I use the difference between the return on loan and the policy rate as a measure of external financing costs.

The financial sector of the economy is left largely unrestricted in the presence of macroeconomic shocks as the SVAR framework is based on a minimal set of sign restrictions. Table 2.2 gives an overview of the initial reactions of the key variable of interest, the EFP, in the selected financial frictions models (see table A.1 and A.2 in appendix A for the remaining two financial variables). Whereas financial

[8]Uhlig (2005) focuses only on the monetary policy shock, which is identified by imposing sign restrictions on the GDP price deflator, the commodity price index, nonborrowed reserves and the federal funds rate for five months.

DSGE models have different implications for the EFP conditional on supply and monetary policy shocks, adverse financial shocks are usually associated with a rise in the premium. Note that a criterion for including a financial DSGE model is that the model analyzed the implications of at least two of the three macroeconomic shocks - supply shocks, demand shocks[9] and monetary policy shocks.

My approach of finding a common denominator among NK models with financial frictions differs from the method employed by Canova and Paustian (2011) and Peersman and Straub (2009), who discriminate among models with and without nominal frictions. The structural analysis, employed in this chapter, relies on financial NK models in the identification and aims at identifying financial frictions that are in line with the estimated behavior of the premium.

An illustration: Different transmission mechanisms and the EFP

As indicated by table 2.1, there is little consensus among financial DSGE models on how the premium behaves in response to macroeconomic shocks. The dynamic reaction of the EFP[10] to shocks depends on how capital accumulation and financial frictions are specified, as has been discussed by Furlanetto et al. (2014). In the following, I will illustrate this along one commonly used financial friction, costly state verification. In their seminal paper, Bernanke et al. (1999) (henceforth, BGG) are the first to introduce costly state verification to analyze the financial accelerator mechanism, i.e., the amplification of shocks due to the existence of financial frictions. The authors find a countercyclical premium conditional on the realization of technology, monetary and net worth shocks. The main intuition for the countercyclical behavior of the premium is the following: The premium develops endogenously and is related to financial positions of firms. If balance sheet conditions of firms are good and their leverage is low, e.g., following positive shocks (causing an increase in real activity), the premium is low (and, hence, countercyclical). When the BGG model is enriched by investment adjustment costs in the capital accumulation process, DeGraeve (2008) finds a procyclical EFP following demand shocks. His demand shock in form of a preference shock has a countercyclical effect on credit and the price of capital, which leads to a procyclical development of leverage and the EFP. A further extension of the BGG framework concerns a debt-deflation channel, whereby Christensen and Dib (2008) specify the loan contract in nominal terms. The introduction of the nominal debt contract results in a procyclical EFP in face of aggregate supply shocks. The

[9]Demand shocks are included in the extended model as a part of the robustness analysis. The baseline model identification represents a broad consensus in financial DSGE models on structural shocks, whereas the extended model is constrained to the subset of financial frictions models that specify demand shocks as preference shocks (as discussed in section 2.3.4)

[10]The EFP is the modeling feature of the debt contract originally described by Bernanke et al. (1999). If the EFP is not present in a particular model as such, I use the difference between the return on loan and the policy rate as a measure of external financing costs.

propagation mechanism is the following: A positive comovement between the EFP and output conditional on technology shocks arises because inflation reacts countercyclically, which affects the real cost of repaying the debt procyclically and, hence, generates a procyclical EFP. As a result of the indexation of the loan contract to the aggregate return, stipulated as in Carlstrom et al. (2014), the EFP is procyclical in response to monetary policy shocks. Hence, it is useful to provide empirical evidence on the dynamics of the EFP and, subsequently, assess to which extent theoretical frameworks fit the data.

Structural financial shocks

The central part of my identification in table 2.1 refers to the financial shock, i.e., the shock to the EFP. An overview of prominent modeling choices of financial frictions and financial shocks is given in table 2.3. Note that the work by Brzoza-Brzezina et al. (2013) compares two main mechanisms used to model financial frictions, in particular, costly state verification in a debt contract à la Bernanke et al. (1999) and collateral constraints. Despite different modeling assumptions and transmission mechanisms, dynamic consequences of financial shocks from a set of DSGE models with financial frictions imply almost uniformly the same sign restrictions on financial variables: An adverse financial shock results in an increase in the EFP, a decline in credit and a decline in stock prices.

Table 2.3: Sign restrictions on EFP, credit and stock prices upon adverse financial shocks

	Shock	Financial friction	EFP	Credit	q
Bernanke et al. (1999)	wealth	CSV	+	-	-
Carlstrom et al. (2014)	net worth	CSV	+	-	-
Christiano et al. (2010)	bank funding	CSV	+	-	-
Christiano et al. (2010)	liquidity buffer	CSV	0	-	-
Cúrdia and Woodford (2010)	bank technology	heterogeneity	+	-	NA
Cúrdia and Woodford (2010)	bad loans	heterogeneity	+	-	NA
Gerali et al. (2010)	bank capital	collateral constraint	+	-	-
Gertler and Karadi (2011)	net worth	moral hazard	+	-	-
Gertler and Karadi (2011)	capital quality	moral hazard	+	-	-
Meh and Moran (2010)	bank funding	moral hazard	+	-	-
Brzoza-Brzezina et al. (2013)	net worth	CSV	+	+	-
Brzoza-Brzezina et al. (2013)	LTV	collateral constraint	0	-	-
Brzoza-Brzezina et al. (2013)	spread	collateral constraint	+	-	-

Notes: The second column describes a type of financial shock. The third column states a financial friction arising in the model. q stands for stock prices, CSV for costly state verification and LTV for the loan-to-value ratio. A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; a "0" indicates a zero-response of the variable on impact; "NA" indicates that the model does not include a specific variable.

Whereas most financial DSGE models generate unanimous dynamics of financial variables (credit, EFP, stock prices) in response to financial shocks, the models differ in their implications regarding the dynamics of inflation and nominal interest rates, as specified by table 2.4. Theoretical models embody both deflationary and inflationary nature of financial shocks. By not including inflation in my identification, I allow the data to speak for themselves as argued by Uhlig (2005). By avoiding an a priori viewpoint on the financial disturbance as a demand-like disturbance,[11] my analysis remains agnostic about the impact response of inflation. For a similar reason, Hristov et al. (2012) and Fornari and Stracca (2013) take no stand on inflation. Furthermore, in order to sufficiently differentiate financial shocks from monetary shocks and aggregate supply shocks, monetary easing by the central bank following the former shocks is specified by assumption.

Table 2.4: Sign restrictions on output, inflation and nominal interest rates upon adverse financial shocks

	Shock	Financial friction	Y	π	R
Carlstrom et al. (2014)	net worth	CSV	-	-	-
Christiano et al. (2010)	bank funding	CSV	-	+	+
Christiano et al. (2010)	liquidity buffer	CSV	-	-	-
Cúrdia and Woodford (2010)	bad loans	heterogeneity	-	-	-
Gerali et al. (2010)	bank capital	collateral constraint	-	+	+
Gertler and Karadi (2011)	net worth	moral hazard	-	-	-
Gertler and Karadi (2011)	capital quality	moral hazard	-	-	-
Meh and Moran (2010)	bank funding	moral hazard	-	+	+
Brzoza-Brzezina et al. (2013)	net worth	CSV	0	+	+
Brzoza-Brzezina et al. (2013)	LTV	collateral constraint	-	-	-
Brzoza-Brzezina et al. (2013)	spread	collateral constraint	-	+	-

Notes: Y stands for real output, π for the inflation rate, R for the nominal interest rate. A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; a "0" indicates a zero-response of the variable on impact.

2.3 Results

2.3.1 Dynamics of the EFP

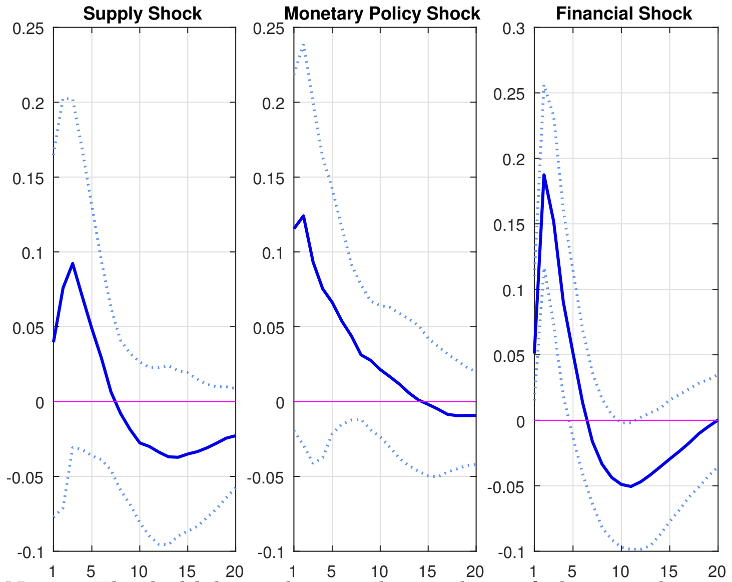
Figure 2.1 depicts the impulse responses of the external finance premium to the supply shock, the monetary shock and the financial shock using the identification scheme in table 2.1. The median estimated response[12] of the premium is countercyclical following all three shocks,[13] i.e., the premium rises initially and real GDP falls. The conditional countercyclical movement of the EFP is consistent with the

[11]See Gambetti and Musso (2017) and Furlanetto et al. (2014) for the analysis of financial shocks as demand-side disturbances.

[12]Since the SVAR with sign restrictions generates wide credible sets in most applications, estimates are statistically insignificant (see, e.g., Canova and Paustian, 2011). Hence, impulse response functions will be interpreted with the help of median estimates.

[13]The short term behavior of median estimated responses of the premium is compared with their theoretical counterparts in table 2.2.

Figure 2.1: External finance premium



Notes: The bold lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation shock. The vertical axis is expressed in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

predictions from various theoretical models (DeGraeve, 2008; Christiano et al., 2010; Gerali et al., 2010; Gertler and Karadi, 2011, to name a few models summarized in table 2.2). In other words, the countercyclical behavior of the premium arises in theoretical frameworks including various types of financial frictions (CSV, moral hazard, collateral constraints).

My empirical evidence does not favor the presence of the Fisher effect, i.e., a debt deflation channel (e.g., an optimal debt contract in nominal terms as stipulated by Christensen and Dib, 2008). Neither is the modeling of heterogeneous financial needs (e.g., Cúrdia and Woodford, 2010) favored by the data. These theoretical models predict a procyclical movement of the EFP conditional on the realization of the supply (technology) shock. However, the estimated impulses responses cannot help to identify a dominant financial friction. Put differently, using the common information regarding three shocks from financial NK models, I find that a subset of financial frictions are consistent with my conditional empirical evidence - an increase in the premium on impact following adverse supply and monetary policy shocks.

My findings are in line with Furlanetto et al. (2014) with respect to the supply shock and differ with respect to the monetary policy shock. The key difference is the identification of the financial shock: While they consider financial disturbances to have deflationary nature, I let the data speak. Furthermore, Furlanetto et al.

(2014) also identify structural demand and investment shocks (using restrictions on the ratio of investment and output, as well as stock prices), whereas my baseline framework models monetary policy shocks explicitly as a type of demand disturbances. Hence, including the demand shock in the extended model helps to provide a sharper identification and, possibly, to deliver a clearer picture of the conditional dynamics of the EFP. In the robustness analysis, I account for possible differences between structural demand shocks and financial (monetary) shocks. I find that the main results regarding the cyclicality of the EFP over the short-term continues to hold.

2.3.2 Impulse response analysis

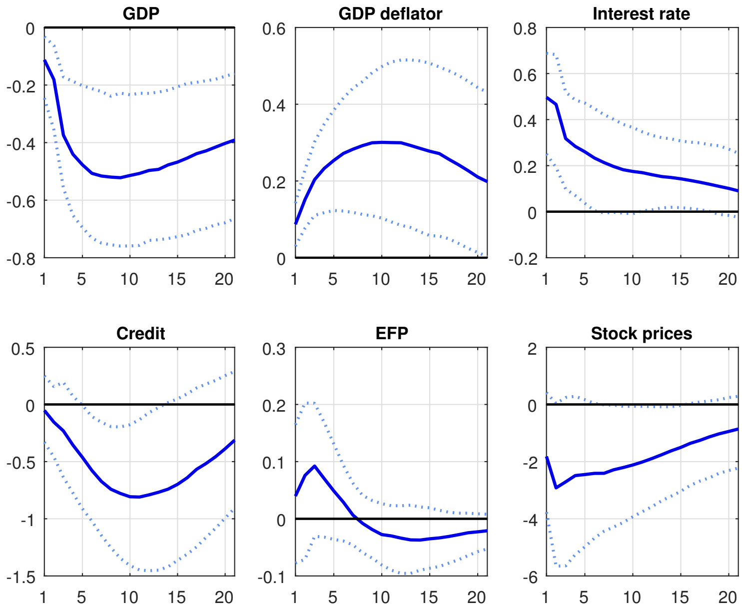
While the focus of this chapter is the dynamics of the EFP, it is interesting to discuss to which extent the model's predictions for other variables are consistent with theoretical predictions. The following figures show the impulse responses of the endogenous variables to the identified structural shocks, specified as in table 2.1. In particular, I will comment on the estimated impulse response functions of remaining unrestricted variables in relation to their theoretical counterparts, summarized in tables in appendix A. As already explained, most SVARs with sign restrictions generate wide credible sets and, therefore, the following impulse response functions will be interpreted with the help of median estimates.

Conditional on an adverse supply shock, depicted in figure 2.2, the EFP (measured by the GZ credit spread) increases. Real GDP and prices (together with the interest rate) move into opposite directions. Stock prices and credit fall and recover only slowly, which is in line with the implications from most of financial DSGE models considered in table A.1 and A.2 in appendix A.

Now I will turn to the analysis of an unexpected increase in the interest rate. The adverse one standard-deviation monetary policy shock causes a decrease in real GDP and the GDP deflator by identifying assumption. Restrictive monetary policy is effective only in the first two periods. The interest rate rises by 10 basis points initially and falls by the same amount in the following periods. This result is comparable with the median impulse response of the nominal interest rate in the analysis by Uhlig (2005), whose sign restriction on the nominal rate has a comparable duration. Contrary to Uhlig (2005), my model reports an unambiguous decline in real GDP as a result of the imposed sign restriction, which is derived from NK models.

It is worth noting that the structural model generates an increase in stock prices and the credit volume, which stands in contrast to the predictions from theoretical models outlined in table A.1 and A.2 in appendix A. Galí and Gambetti (2015) report a similar result on stock prices in the context of a time-varying VAR and, therefore, argue that their result provides empirical evidence against the

Figure 2.2: Adverse aggregate supply shock



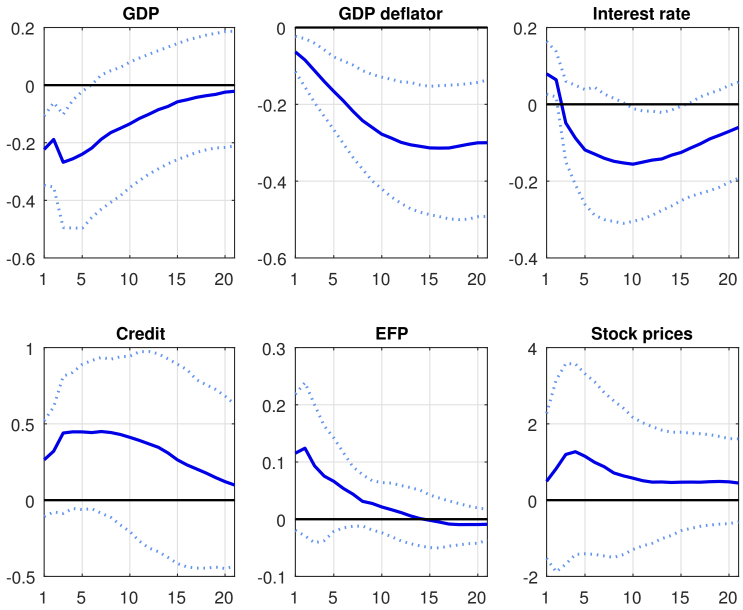
Notes: The bold lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation aggregate supply shock. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

conventional wisdom that contractionary monetary policy shocks have a negative effect on asset prices. Additionally, the positive development of the credit volume appears to be a result of a slow readjustment of the market. It takes time for the new credit terms to be effective in financial contracts.

The GZ credit spread increases much more than the initial rise in the interest rate. This can reflect the degree of financial frictions in the corporate sector that intensifies the propagation of the shock. The countercyclical movement of the EFP, as already argued, is the feature of numerous financial DSGE models.

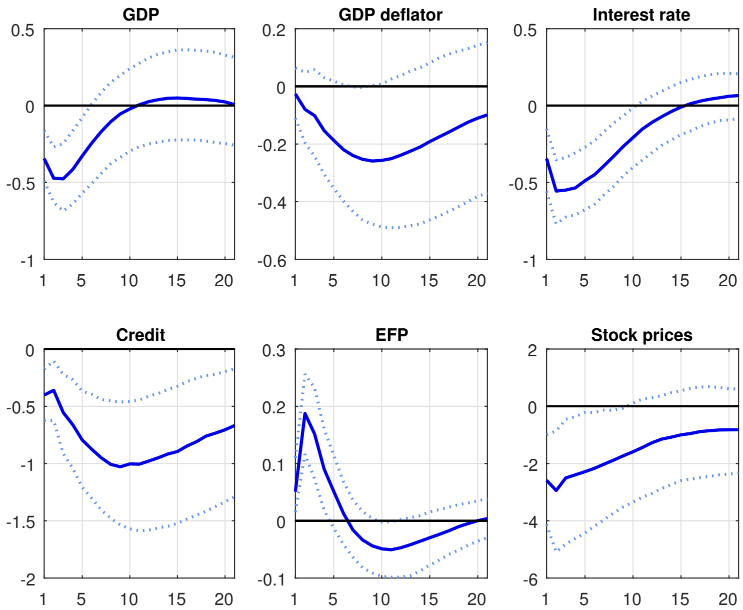
The financial shock is depicted in figure 2.4. My results indicate that an unexpected rise in the EFP (by 20 basis points) leads to a prolonged contraction of output and a significant easing of the monetary policy (by 50 basis points). These results are in line with the results established in the literature: Financial shocks have a persistent impact on the real economy (see Gilchrist and Zakrajšek, 2012; Meeks, 2012). Median estimates on prices speak clearly in favor of the deflationary nature of financial shocks (see, e.g., Gilchrist and Zakrajšek, 2012; Furlanetto et al., 2014). The magnitude of the increase in the EFP should not be surprising given that the measure of the premium is based on the broad coverage of firms with different credit standings. For a comparison, Meeks (2012) reports that his estimated one standard-deviation credit spread shock generates initially a 50-basis-point increase in the high yield spread, which is a difference between the speculative-grade corporate

Figure 2.3: Adverse monetary policy shock



Notes: The bold lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation monetary policy shock using identification scheme in table 2.1. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

Figure 2.4: Adverse financial shock



Notes: The bold lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation financial shock. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

bond yield and the closely matched government bond yield. Unlike my measure for the premium, the high yield spread measure is related to firms subject to the high risk of default.

2.3.3 Implications for modeling financial frictions

Many theoretical frameworks with a rich modeling of the financial sector have uncovered different transmission channels of disruptions in financial markets. The diversity in the modeling of the financial sector addressed many different questions related to the financial crisis, however, the most important one remains open: Which modeling framework is supported by the data? What can we learn about financial frictions from the structural analysis?

This work identified financial shocks and macroeconomic shocks using the common information across different theoretical frameworks, which can be interpreted as the smallest common denominator in the modeling of financial frictions. The prime focus is placed on the conditional dynamics of the EFP, as most DSGE models differ with respect to the dynamics of the EFP. The identification of relevant financial frictions models is undertaken by comparing the empirical evidence on the credit spread in the short term (up to one year) with the theoretical predictions regarding the EFP. Credit and the price of capital decline almost uniformly in response to adverse macroeconomic shocks across the models, and therefore it is difficult to differentiate models along these lines.[14] As I concentrate on the median estimates (most of which are not statistically significant), the caveat applies that the identification of an empirically relevant financial friction should be interpreted with some care.

The structural analysis indicates that the premium is countercyclical following monetary policy shocks and supply shocks. The countercyclical nature of the EFP is consistent with various DSGE models with financial frictions, e.g., Bernanke et al. (1999); Gertler and Karadi (2011); Gerali et al. (2010). On the other hand, transmission mechanisms associated with financial DSGE models, which generate a procyclical EFP, are not consistent with my empirical estimates. For example, nominal debt contracts of Christensen and Dib (2008) and heterogeneous needs of borrowers and savers, as modeled by Cúrdia and Woodford (2010), incorporate transmission mechanisms that are not supported by my empirical results on the EFP.

The nutshell intuition for the countercyclical EFP in the aforementioned models is the following: A negative comovement between the EFP and output conditional on technology (supply) shocks arises because inflation reacts countercyclically,

[14] Recall that the empirical impulse response functions of these two variables coincide to a larger extent with their theoretical counterparts. The exception is the reaction of the credit volume in the case of the monetary shock.

which leads to a countercyclical development of leverage and the EFP. The unexpected monetary tightening decreases aggregate demand, which together with the decline in the price of capital and the higher value of debt, results in an increase in the EFP (making it countercyclical). Through widening of the premium, the propagation of shocks gets accelerated in models with financial frictions.

There are many theoretical model candidates that explain responses observed in the data. The nature of financial frictions can take different forms: Moral hazard problems arise as a result of misbehavior of bankers along the lines of Gertler and Karadi (2011). Costly verification is undertaken by financial intermediaries due to the asymmetric information problem between borrowers and lenders, as in the setups by Bernanke et al. (1999); DeGraeve (2008). Collateral constraints combined with monopolistic competition between different bank branches are analyzed by Gerali et al. (2010) among others.

2.3.4 Robustness of the results

Extended model

The baseline model represents a parsimonious framework that identifies structural shocks using restrictions that are derived from a wide range of financial DSGE models. The problematic aspect of identifying too few shocks is that non-identified shocks, arise somewhere else in the SVAR. In particular, financial shocks could also embody demand shocks, that are not identified. Determining a combination of robust sign restrictions to identify demand shocks is a controversial task. Demand shocks can be preference shocks, government spending shocks or investment shocks. Depending on the type of demand shocks, DSGE models generate different predictions. Moreover, additional identifying restrictions need to be mutually exclusive.

In my proposed identification scheme of the extended model, presented in table 2.5, the structural demand shock corresponds to a preference shock in financial DSGE models. Typically, a negative preference shock induces households shift consumption towards the future. As savings increase and investment rises, the price for capital increases, which reduces the EFP (see, e.g., DeGraeve, 2008, among others).[15] As a result, the extended model is more restrictive than the baseline model.

By disentangling demand and financial shocks in the extended model, I try to obtain a sharp identification of financial shocks. Results from the extended model are included in appendix A (see figures A.2, A.3, A.4 and A.5). Main findings regarding the cyclicality of the EFP do not change in the extended model, confirming

[15] The overview of demand shocks in appendix A shows that there is a less clear consensus which restriction to impose on financial variables (c.f., credit and the price of capital) to identify demand shocks. Given that most of considered frameworks, which model preference shocks, generate a decline in the EFP following adverse demand shocks, I proceed with a restriction on the EFP.

Table 2.5: Sign restrictions in the extended model

	Supply	Demand	Monetary	Financial
Real GDP	-	-	-	-
GDP deflator	+	-	-	NA
Nominal interest rate	+	-	+	-
Credit	NA	NA	NA	-
EFP	NA	-	NA	+
Stock prices	NA	NA	NA	-

Notes: A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; "NA" indicates that the impact impulse response can be positive, negative or zero and, therefore, no sign is assigned. All the shocks represent adverse disturbances.

the countercyclical development of the EFP over the short term following supply and monetary policy shocks. The dynamics of most variables are the same as in the baseline model. However, two different results will be elaborated in the following.

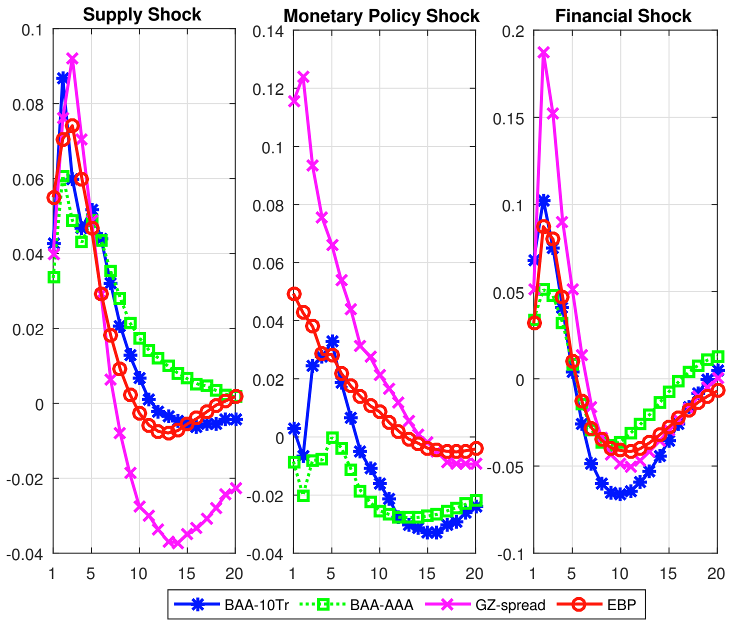
Reaction of stock prices to monetary policy shocks: The transmission of the monetary policy shocks seems to change in the extended model. Stock prices react negatively to the contractionary monetary policy shock (see figure A.4), which is consistent with the conventional wisdom. These results suggest that if I do not clearly differentiate between monetary policy shocks and structural demand shocks, as in the baseline model, monetary policy shocks embed also other demand shocks which might drive the reaction of stock prices in the opposite direction. This result is interesting, especially in the light of the recent debate by Galí and Gambetti (2015). A further explanation is presented by Canova and Paustian (2011), who argue that properties of the monetary policy shock can be mismeasured if too few sign restrictions are imposed.

Reaction of the GDP deflator to financial shocks: Median estimates on the GDP deflator speak for the possibility of the inflationary nature of financial shocks (see figures A.5). Note that the baseline model indicates that financial shocks have typically deflationary nature, whereas the extended model, which takes seriously differences between demand and financial shocks, implies the opposite. To my knowledge, most of the literature did not address the role of price dynamics following financial shocks; or, if anything, the empirical research emphasized the disinflationary effect of financial shocks (see Gilchrist and Zakrajšek, 2012; Furlanetto et al., 2014). The recent theoretical framework by Gilchrist et al. (2014) addressed the possibility of increased prices in face of negative financial shocks. The rationale for the increase in inflation, argued by the authors, is the following: Their NK model allows that firms' pricing setting decision affect firms' market shares. Using two types of firms (financially strong and weak firms), they show that firms with a limited access to finance and, therefore, in weak financial positions, do not proceed with investment opportunities and increase prices to keep their market shares.

Alternative measures of the EFP

My structural analysis is based on a specific proxy for the EFP, the GZ credit spread. To counter a possible critique related to the choice of the proxy, I employ further spread indicators used to measure the EFP: BAA-AAA spread, BAA-10Tr spread and the EBP, described in section 2.2.1. Figure 2.5 plots median impulse responses of these spreads using the model specification in table 2.1.

Figure 2.5: Impulse responses of alternative measures of the EFP



Notes: Lines denote the median impulse responses. The estimated model is based on identification in table 2.1. The impulse responses are related to an adverse one standard deviation shock. The vertical axis is expressed in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

The reactions of credit spreads to shocks are comparable to the baseline measure of the EFP: Proxies of the premium react countercyclically to supply shocks and monetary policy shocks over the short term. There is some heterogeneity across the estimated responses, which can be explained by a different class of firms considered by alternative measures: First, the BAA-AAA spread and the BAA-10Tr spread are related to firms with high credit standing. Especially, the result regarding the former spread suggests that the restrictive monetary policy depresses the premium of corporate firms with low default risks. This result suggests that the transmission mechanism of the monetary policy shock can vary with the degree of financial frictions in the corporate sectors. As already argued, the GZ credit spread reflects the premium that non-financial firms pay for their unsecured corporate debt, taking into account all different rating categories and, therefore, being more representative for the whole economy. Second, the standard corporate credit spreads do not use a reference rate with the same maturity profile as corporate bond yields, implying that potential effects from maturity profile of reference yields can matter. This problematic aspect of standard spreads is solved by construction of the GZ credit spread.

Robustness check: Excluding the Great Recession and the pre-Volcker era

To analyze whether the results are driven by the financial crisis of 2007-2009, I consider the dataset excluding the observations from 2007Q4 onwards (according to the NBER dating of the recession). Furthermore, the conduct of monetary policy has significantly changed with the Fed presidency of Paul Volcker. In this context, much of the empirical research on monetary policy shocks has incorporated a shift in the monetary policy stance as of 1979Q3. Therefore, I exclude also a part of the data sample related to the pre-Volcker era.

The analysis confirms the main results on an economic downturn following adverse financial shocks, however, the credible sets are wider (see figure A.7 in appendix A). Main estimates concerning aggregate shocks and the behavior of the premium remain the same. These results confirm the previously found cyclicality of the EFP (see figure A.6 and A.7 in appendix A). As expected, the estimated rise in the EFP upon the adverse financial shock is subdued in comparison to the result based on the whole sample.

Residual check: Do adverse financial shocks measure productivity losses?

Financing booms in the US are positively associated with productivity changes (see Jermann and Quadrini, 2007). To analyze whether financial shocks are indeed measuring financial disturbances as opposed to productivity changes, I examine a relationship between financial shocks and the change in total factor productivity (TFP).[16] First, the correlation between the SVAR-estimated financial shock and the total factor productivity is 0.09 and statistically insignificant (p-value of 55%). Second, I regress normalized TFP on its lag and the contemporaneous estimates of structural shocks (aggregate supply, monetary policy and credit spread shocks). The estimated equation is an OLS regression in the spirit of Galí and Rabanal (2004) and reads:

$$\begin{array}{rcl} TFP_t & = & \underset{(0.64)}{-0.03TFP_{t-1}} - \underset{(0.01)}{0.19\varepsilon_t^{AS}} - \underset{(0.41)}{0.06\varepsilon_t^{MP}} + \underset{(0.55)}{0.04\varepsilon_t^{FS}}. \end{array}$$

Note: The p-values are reported in the brackets.

[16] I use the measure of total factor productivity adjusted for utilisation provided by Basu et al. (2006). The data series in quarters is reported by Fernald (2012).

My estimates show that the aggregate supply shock is relevant for the fluctuations in TFP (as its coefficient is significant). None of the other estimated shocks are relevant for the changes in TFP. In particular, the financial shock appears not to be a cause of the productivity fluctuations.

2.4 Conclusion

Despite extensive research on financial markets and financial frictions, there is no workhorse model with financial frictions that is fully supported by data. This paper represents one possible approach to identify relevant financial frictions.

The main focus of the paper is to analyze the dynamics of the EFP in response to macroeconomic shocks when shocks are identified in a theory-consistent manner. Using common information from various financial DSGE models, the minimal set of sign restrictions is employed to disentangle financial shocks from macroeconomic shocks. The SVAR model is used to gauge financial frictions that are in line with the data.

The structural empirical analysis shows that the EFP is countercyclical following supply and monetary policy shocks. This is good news for major financial frictions models such as Bernanke et al. (1999); Gertler and Karadi (2011); Gerali et al. (2010), as these models generate the cyclicality of the premium observed in the data. Furthermore, it is indicated that different types of financial frictions can generate transmission mechanisms that are consistent with the conditional dynamics of the EFP.

My identification of structural shocks is based on a common denominator from financial DSGE models. There are some possible avenues for future research. First, by considering a smaller set of financial DSGE models, it would be possible to identify certain types of financial shocks, e.g., shocks arising in credit market or shocks associated with banks' capital. Second, given my weak evidence on the inflationary nature of financial shocks, it would be useful to better understand the dynamics of inflation following financial shocks. For example, the analysis by Peersman and Wagner (2014) provides some evidence in this respect, as they differentiate among bank lending shocks, securitizaton shocks and risk taking shocks, and show that the latter shocks have inflationary tendency. Third, estimating large SVAR models with a more elaborate representation of the financial sector and more financial shocks can possibly help to identify a workhorse financial frictions model.

Chapter 3

Corporate debt composition and business cycles

Abstract

Based on empirical evidence, I propose a DSGE model with two financial sectors to analyze the role of the corporate debt composition (bank versus bond financing) in the transmission of economic shocks. It is shown that in the presence of monetary and financial shocks, cyclical changes in the corporate debt composition significantly attenuate the effects on investment and output. An additional result of the theoretical model is that a bank-dependent economy is more affected by financial shocks, which is in line with recent empirical results by Gambetti and Musso (2017), who report stronger real effects of loan supply shocks in Europe (with an excessive reliance on bank debt) than in the US.

Keywords: Debt financing, bank loans, corporate bonds, financial frictions.
JEL Classification: E32, E44, C68.

3.1 Introduction

How do changes in the corporate debt composition (bank debt versus capital market debt) affect the propagation of macroeconomic and financial shocks? It is well documented that the corporate debt composition varies over the business cycle (see, e.g., Adrian et al., 2012; Becker and Ivashina, 2014). The variation in the external financing mix seems to matter quantitatively for the dynamic consequences of the monetary policy shock (see empirical evidence by Kashyap et al., 1996; Oliner and Rudebusch, 1996). Therefore, it is natural to ask what role cyclical variations in corporate debt play in the transmission of economic shocks.

To address this question, I first provide additional empirical evidence on the dynamics of real output, investment and corporate debt composition based on an

SVAR with sign restrictions.[1] I show that the conditional dynamics of the debt composition depend on the type of economic shock. In particular, when the debt composition reacts more strongly to the shock, the response of investment is less persistent. Second, I develop a financial DSGE model featuring bond and loan financing in order to analyze the role of debt composition in the propagation of macroeconomic and financial shocks. I show that an increase in capital market debt in reaction to monetary and financial shocks attenuates the response of investment and real activity. When bank credit is the only source of external financing (bank-dependent economy), financial shocks have stronger contractionary effects on the real economy than in an economy with bank and capital market debt. This result is in line with the empirical findings by Gambetti and Musso (2016), who report stronger real short-term effects of loan supply shocks in Europe than in the US. Note that the ratio of bank to non-bank debt is almost eight times higher in Europe than in the US (see DeFiore and Uhlig, 2011).

In the theoretical model, banks supply loans to small firms and mutual funds make bond financing available to large firms, which is meant to capture the empirical finding by Colla et al. (2013) on the debt specialization of large and small US firms. Banks face a leverage constraint, modeled as in Gertler and Karadi (2011), which determines the amount of loans granted to firms. A tightening of banks' capital constraints causes a decrease in banks' supply of loans, which adversely affects the financing and investment decisions of small firms. Therefore, the changes in the conditions related to the external financing of small firms are effective through a bank lending channel. The funding problem of large firms is modeled via optimal debt contracts with mutual funds as in Bernanke et al. (1999), whereby mutual funds are not exposed to any capital requirement. The capital market channel emphasizes the ability of unconstrained mutual funds to underwrite bond contacts of leveraged large firms in return for an increased finance premium. Additionally, the degree of the asymmetric information problem between large firms and mutual funds is not severe, i.e., mutual funds can recoup the assets of firms without incurring large costs, which is line with the notion that dispersed mutual funds do not exercise high monitoring effort (see Gorton and Winton, 2003).

I consider two financial shocks hitting the financial sector of my model. The first one is a banking shock which causes a confidence loss in this sector leading to tighter leverage constraints and an increase in bank finance premia. The second one is an economy-wide financial shock that affects both sectors causing an increase in the distrust of banks and an inefficiency in the auditing of large firms by mutual funds. The latter shock is calibrated to match the empirical evidence on bank and non-bank premia following the estimated financial shock.

[1] The sign restrictions are imposed to identify supply, demand and financial shocks. Imposed sign restrictions are compatible with predictions from a wide range of financial DSGE models.

The nutshell intuition for the relevance of the debt composition in the propagation of shocks is the following: Contractionary shocks (resulting in a rise in finance premia on bank loans) impair the ability of leveraged banks to provide loans (leading to credit tightening) which adversely affects bank-financing dependent firms (c.f., Gertler and Karadi, 2011). Bond-financing dependent firms can nevertheless issue bonds in times of rising bond finance premia. Note that a stronger increase in bank finance premia relative to bond finance premia leads to a relative decrease in loan-to-bond financing and investments of the respective firm sector. Financial shocks trigger stronger movements in finance premia and lending volumes, which in turn results in substantial negative effects on the real economy.

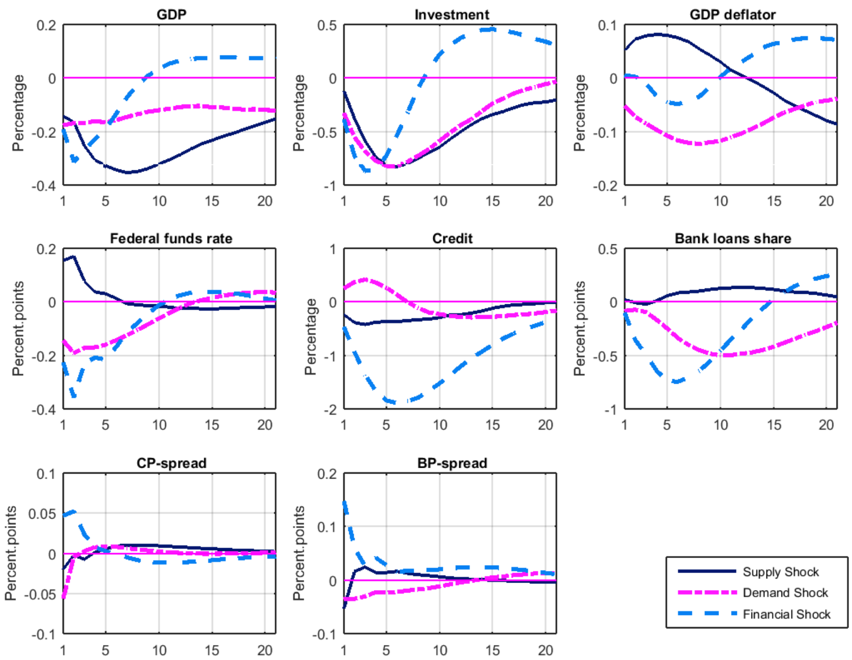
This paper is not alone in analyzing the role of corporate debt composition in the real economy. DeFiore and Uhlig (2015) also show that a shift from bank to bond financing mitigates the negative effects of financial shocks on the real economy. However, there are some important differences regarding empirical facts and model features between my and their work. Using the US data, I estimate financial shocks in a SVAR framework and show that bank debt is relatively more expensive than capital market debt. DeFiore and Uhlig (2015) document that the cost of capital market financing increased more than the cost of bank financing in Europe during the financial crisis of 2008-09. In my DSGE model I allow for leveraged banks to restrict credit supply in times of tight lending standards, whereas DeFiore and Uhlig (2015) do not explicitly model the role of banks. Therefore, my theoretical setup considers the extent to which a bank-lending channel has effects on investment. Furthermore, I try to understand the role of the debt composition in the transmission of standard business cycle shocks, whereas DeFiore and Uhlig (2015) focus only on financial shocks. However, my SVAR evidence, together with the evidence from Kashyap et al. (1996) and Oliner and Rudebusch (1996), shows that the change in the external financing mix is not only associated with financial shocks.

The remainder of the paper is organized along the following lines. Section 2 presents the empirical evidence. Section 3 describes the model setup. Section 4 discusses the main results. Section 5 concludes.

3.2 Empirical evidence on the corporate debt composition

I first present some evidence on the dynamics of macroeconomic and financial variables. More precisely, I use an SVAR with sign restrictions to identify supply, demand and financial shocks. The former two are standard drivers of business cycles, whereas financial shocks have been only lately considered as an important source of macroeconomic fluctuations (see, for example, Gilchrist and Zakrajšek, 2012). The imposed sign restrictions comply with the predictions from a large class of New Keynesian models with financial frictions.[2] The dynamic consequences of economic shocks motivate the theoretical model with the corporate debt composition developed in section 3.3.

Figure 3.1: SVAR evidence



Note: The lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The impulse responses are related to an adverse one-standard deviation shock. The horizontal axis is in quarters. Time period: 1980:Q1 to 2014:Q2.

Figure 3.1 displays median impulse responses of real GDP, real investment spending, the GDP deflator, the federal funds (FF) rate, credit, the bank loans share (loan-to-bond ratio), the CP-spread (commercial paper rate - FF rate) and the BP-spread (bank prime rate - FF rate) based on the estimated model from 1980:Q1 to 2014:Q2. All variables are for the US and specified in logs, except for the spreads and the FF rate, which are expressed in percentage points. The empirical exercise aims at providing additional evidence on real variables and financial indicators of interest - the corporate debt composition, measured as the relative share of bank loans to corporate bonds, the cost of bank and non-bank debt, measured by the

[2]See table 2.4in appendix B. The discussion of the extended model specification is elaborated in the second chapter. Given the limited importance of monetary policy shocks for business cycle fluctuations, I excluded these shocks from the empirical analysis. For the dynamic effects of monetary policy shocks on the corporate debt composition, see (Kashyap et al., 1996; Oliner and Rudebusch, 1996).

BP- and CP-spread, respectively,[3] for the theoretical analysis conducted in section 4.3. It should be noted that not every impulse response is statistically significant; however, it gives the general tendency of the variable. The respective credible sets are computed and reported in appendix B.

The estimated financial shock represents an exogenous disturbance to the BP-spread that leads to an increase in both credit spreads and a decline in credit volume. Similar to the findings by Gilchrist and Zakrajšek (2012), I show that investment and real output fall significantly in response to the adverse financial shock (see figure B.2 in appendix B); however, they recover after ten quarters. The ratio of bank loans to bonds declines significantly, whereas the bank premium, i.e., the BP-spread, increases almost three times more than the non-bank premium, the CP-spread. In contrast to DeFiore and Uhlig (2015), I document a relatively stronger increase in the bank spread than in the spread related to capital market finance conditional on the identified financial shock. The most striking feature in figure 3.1 is a strong cyclical variation in investment and the corporate debt composition. Both variables deviate substantially from their mean values, tend to overshoot over the medium term, and then revert to their means.

Negative supply shocks cause a persistent decline in investment and output. After initial declines in both spreads, bank spreads rise more than spreads for capital market finance. The estimated shock appears to cause an increase in the loan-to-bond ratio. For completeness, demand shocks lead to declines in investment, output, the bank-to-bond ratio and credit spreads.

To summarize, the cyclical variation of the corporate debt composition differs depending on the type of shock. Bank spreads increase more in reaction to financial shocks and aggregate supply shocks than non-bank spreads. The identified financial shock produces a strong reaction of the debt composition and a rather short-lived effect on investment. In the following, the model is developed to match this empirical evidence.

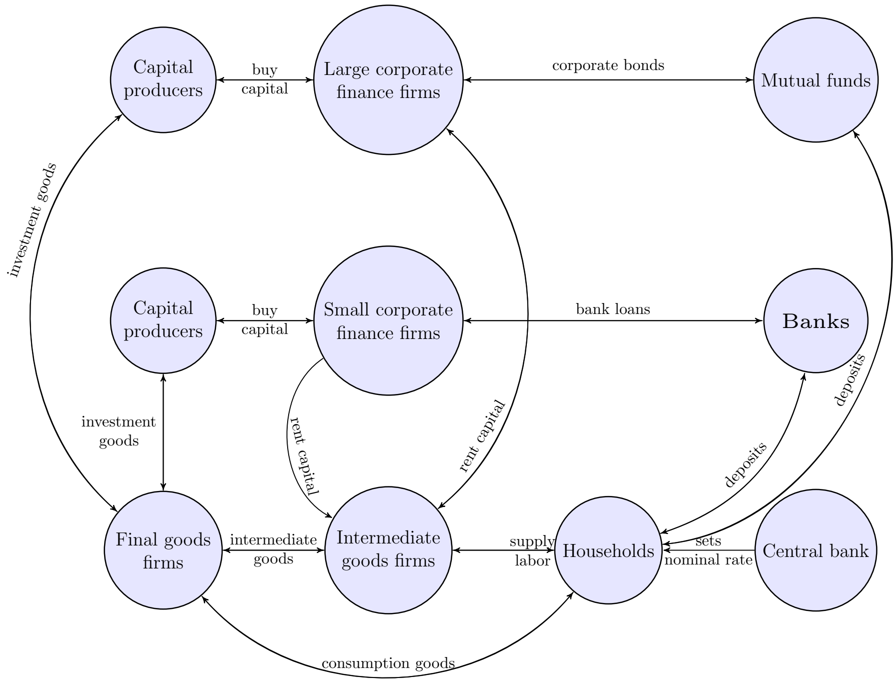
3.3 The model

I introduce two types of external financing - bank and non-bank debt - associated with small and large corporate finance firms,[4] respectively, into a medium-scale

[3]Two spreads are used to capture the costs of short-term bank and capital market finance. Due to the unavailability of data, I use commercial paper as a proxy for capital market finance.

[4]These firms are in charge of financing decisions, similar to corporate finance divisions of firms. The differentiation between small and large corporate finance firms matches the following empirical evidence: Cantillo and Wright (2000) show that large firms use bond financing, whereas smaller firms rely only on bank financing. Colla et al. (2013) and Rauh and Sufi (2010) found that the majority of US firms tend to concentrate on one type of debt. However, a certain degree in heterogeneity in debt structure is found among the large rated firms, whereas the small unrated firms tend to specialize in bank financing.

Figure 3.2: Model overview



DSGE model. Two financial frictions, moral hazard and costly state verification, are motivated by the empirical evidence in the second chapter. Banks are modeled as depository institutions and "relationship-lenders", as in the setup by Gertler and Karadi (2011). Due to a moral hazard problem between depositors and banks, banks can supply only as much credit to small firms as indicated by their leverage constraint. I specify an adverse banking shock that results in a confidence loss in the banking sector and leads to a tightening of bank credit supply. On the other hand, capital market debt (corporate bond) issuance is considered as "unmonitored lending", since dispersed bond holders do not exercise direct monitoring and evaluation of outcomes of firms' projects.[5] To capture the notion of dispersed investors and their monitoring effort, I use a debt contract with costly state verification as specified by Bernanke et al. (1999). I assume that the asymmetric information problem between mutual funds and large corporate finance firms is not severe, so that the recouping of the returns in the case of default of these firms is not costly for mutual funds. Note that I also specify that the adverse economy-wide financial shock affects the ability of mutual funds to verify the realized returns from large firms (by increasing monitoring costs) in addition to causing a loss in confidence in the banking sector.

[5] See the discussion on differences between bank loans and corporate bonds in Gorton and Winton (2003).

The model economy is populated by seven different types of agents: households, corporate finance firms, intermediate firms, final goods firms, capital goods producers, lending banks and mutual funds. The bird's eye view of the model economy is given in figure 3.2. Households consume, supply labor and save via depositing resources with financial intermediaries. Corporate finance firms obtain credit in the form of bank loans and corporate bonds in order to finance their investments in physical capital. The retail sector is monopolistically competitive. The retailers or intermediate goods firms combine the physical capital from two sectors with the labor to produce differentiated products and set prices. The final goods producers combine all the intermediate goods and make it available to the household. The central bank conducts the monetary policy by following a Taylor-type monetary policy rule.

3.3.1 Households

There is a continuum of households with a unit mass. As in Gertler and Karadi (2011), I assume that a fraction f of households are workers, whereas a fraction $1-f$ manage banks. Workers earn their wage income every period, whereas bankers reinvest their profits from bank loans until they exit the banking sector. The accumulated profits are then transferred to its family. To ensure that both fractions of the households face the same consumption stream, perfect consumption insurance within the household family is assumed. The household consumes, works and saves in the form of riskless short-term government bonds (deposits), which is issued by banks and mutual funds.[6] In short, the household solves the following intertemporal maximization problem:

$$\max_{C_t,D_t,L_t} \quad E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln(C_t - hC_{t-1}) - \frac{\psi_L}{1+\phi_L} L_t^{1+\phi_L} \right)$$

subject to a sequence of constraints:

$$C_t + D_t = R_{t-1}D_{t-1} + w_t L_t + \mathit{\Pi}_t, \quad \text{for } t \in 0, 1, 2...$$

where $0 < \beta < 1$ and $\psi_L, \phi_L > 0, 0 < h < 1$ denote, respectively, the household's discount factor, the weight on the disutility of labor, the inverse of the labor supply elasticity and the degree of habit formation. C_t denotes real consumption, w_t real wage rate, D_t holdings of one-period risk-free debt, R_t risk-free gross return between $t-1$ and t, L_t hours worked, $\mathit{\Pi}_t$ profits from the ownership of financial and non-financial firms, net the transfers that the household gives to its members entering the financial system in t and lump-sum receipts from cost of monitoring

[6]Households do not make a portfolio choice, as both financial intermediaries pay the same return, the real interest rate.

by mutual funds.

The first order conditions with respect to C_t, L_t and D_t are given by:

$$\lambda_t = \frac{1}{(C_t - hC_{t-1})} - \frac{\beta h}{(E_t C_{t+1} - hC_t)}, \quad (3.1)$$

$$1 = \beta E_t \{R_t \Lambda_{t,t+1}\}, \quad (3.2)$$

$$w_t = \frac{\psi_L L_t^{\phi_L}}{\lambda_t}, \quad (3.3)$$

where λ_t denotes the Lagrange multiplier and $\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$.

3.3.2 Intermediate goods firms

There are infinitely many monopolistic firms on the interval $[0,1]$, which produce differentiated intermediate goods. A representative firm i produces output $Y^m_{i,t}$ using labor $L_{i,t}$ and capital input $K_{i,t}$:

$$Y^m_{i,t} = A_t K^{\alpha}_{i,t} L^{1-\alpha}_{i,t}, \quad (3.4)$$

with $0 < \alpha < 1$ and A_t represents aggregate technology. The capital input is a composite of two types of capital, $K^S_{i,t}$ and $K^B_{i,t}$, provided by small and large corporate finance firms, which are indicated by the respective superscripts S and B, and it is given by:[7]

$$K_{i,t} = \left[\eta (K^S_{i,t})^{\rho} + (1-\eta)(K^B_{i,t})^{\rho}\right]^{\frac{1}{\rho}}, \quad (3.5)$$

where ρ is the degree of substitutability between the two types of capital services and η the share of small firms.

The intermediate firm rents capital and hires labor in competitive markets to minimize its costs, taking the real wage w_t and real rental rates of capital, $r^S_{k,t}$ and $r^B_{k,t}$, as given. Thus, the cost minimization problem reads:

$$\min_{\{L_{i,t}, K^S_{i,t}, K^B_{i,t}\}} \quad C(\cdot) = w_t L_{i,t} + K^S_{i,t} r^S_{k,t} + K^B_{i,t} r^B_{k,t}$$

$$\text{subject to} \quad \text{~(3.4) and ~(3.5).}$$

After substituting the optimal choices back into the cost function and using symmetry, since all firms face the same input prices, the optimality condition yields

[7]Note that after solving cost minimization problem of intermediate firms and assuming symmetry, index i drops. All the individual members are identical within each group, i.e., $K^{S,a}_t = \eta K^S_t$ and $K^{B,a}_t = (1-\eta) K^B_t$, whereby $K^{S,a}_t$ and $K^{B,a}_t$ represent the sector-specific bundles of capital.

the following real marginal costs s_t:

$$s_t = \frac{r^j_{k,t}}{\alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \left(K^j_t\right)^{\rho-1} \left[\eta \left(K^S_t\right)^\rho + (1-\eta)\left(K^B_t\right)^\rho\right]^{\frac{1}{\rho}-1}}, \tag{3.6}$$

which states that the real marginal cost equals the ratio of the rental rate of capital to the marginal product of capital of firms.

The minimization problem also yields the optimality condition for the choice of capital services and labor hours, respectively:

$$\frac{r^{k,B}_t}{r^{k,S}_t} = \left(\frac{K^B_t}{K^S_t}\right)^{\rho-1}, \tag{3.7}$$

$$w_t = s_t \frac{\alpha Y^m_t}{L_t}. \tag{3.8}$$

Intermediate firms also set their prices à la Calvo (1983) in order to maximize the present value of the expected future nominal profits:

$$\max \qquad E_t \sum_{\tau=0}^{\infty} (\beta\theta)^\tau \varLambda_{t,t+\tau}[(\frac{P^*_t}{P_{t+\tau}} \prod_{k=1}^{\tau} \Pi^\iota_{t+k-1} - S_{t+\tau}) Y_{i,t+\tau}]$$

$$\text{subject to} \qquad Y^m_{i,t+\tau} = \left(\frac{P_{i,t+\tau}}{P_{t+\tau}}\right)^{-\epsilon} Y_{t+\tau}.$$

where S_t represents firm's nominal marginal costs. Parameters $\epsilon > 0, 0 < \theta < 1$ denote, respectively, the price elasticity of demand and the degree of price stickiness. The firms which cannot change prices in a given period adjust them according to the indexation rule:

$$P_{i,t} = P_{i,t-1}\Pi^\iota_{t-1},$$

where $\Pi_{t-1} = P_{t-1}/P_{t-2}$ is the gross inflation rate in $t-1$ and the parameter $0 \le \iota \le 1$ controls the degree of backward-lookingness in prices.

First order condition for optimal price setting reads:

$$E_t \sum_{i=0}^{\infty} (\beta\theta)^\tau \Lambda_{t,t+\tau} \left\{ \frac{P^*_t}{P_{t+\tau}} \prod_{k=1}^{\tau} \Pi^\iota_{t+k-1} - \frac{\varepsilon-1}{\varepsilon} S_{t+\tau} \right\} \left(\frac{P^*_t}{P_{t+\tau}}\right)^{-\epsilon} Y_{t+\tau} = 0. \tag{3.9}$$

The solution of the maximization problem equates the newly set price, P^*_t, to the weighted average of all future expected marginal costs, i.e. taking into account the possibility that the newly set price could remain active forever. Using symmetric equilibrium and the law of large numbers, aggregate price index evolves as follows:

$$P_t = \left\{(1-\theta) P^{*1-\epsilon}_t + \theta (P_{t-1}\Pi^\iota_{t-1})^{1-\epsilon}\right\}^{\frac{1}{1-\epsilon}}, \tag{3.10}$$

The equilibrium conditions associated with the optimal choice of price give rise to the New Keynesian Phillips curve with price indexation in the following manner:

$$\Pi_t^* = \frac{\epsilon}{\epsilon - 1} \frac{F_t^m}{Z_t^m} \Pi_t, \tag{3.11}$$

where F_t^m and Z_t^m are defined as $F_t^m \equiv Y_t^m s_t + \beta\theta E_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon} \Pi_t^{-\iota\epsilon} F_{t+1}^m$ and $Z_t^m \equiv Y_t^m + \beta\theta E_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon-1} \Pi_t^{-\iota(\epsilon-1)} Z_{t+1}^m$. Aggregate output, Y_t, is related to the aggregate intermediate output, Y_t^m, in the following way:

$$Y_t^m = Y_t \Delta_t, \tag{3.12}$$

where Δ_t measures the price dispersion, which takes the following form:

$$\Delta_t = \theta \Delta_{t-1} \Pi_t^{\epsilon} \Pi_{t-1}^{-\iota\epsilon} + (1-\theta)^{\frac{-1}{\epsilon-1}} \left(1 - \theta \Pi_t^{\epsilon-1} \Pi_{t-1}^{-\theta(\epsilon-1)}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{3.13}$$

3.3.3 Corporate finance firms and debt financing

The financial sector is composed of a bond and a loan market, implying that there are two types of financial intermediaries: a) banks that accept deposits and lend to small corporate finance firms and b) mutual funds that underwrite corporate bonds issued by large corporate finance firms and thereby channel the funds by the households (see the graphical representation in figure 3.2). Accordingly, the corporate finance firms, who enable the financing of firms, are divided in two groups - large (corporate finance) firms qualify for bond financing whereas small (corporate finance) firms turn to retail banks to obtain loan financing.[8] For convenience, I will refer to two types of corporate finance firms as large and small firms. The modeling approach is supported by the recent findings by Colla et al. (2013) and Rauh and Sufi (2010) who show, using different samples, that the majority of US firms tend to concentrate on one type of debt. Note that the share of firms in each sector is assumed to be fixed, in order to match the characteristics of bank and bond financing in the US; however, this assumption can be relaxed. In the current setting, the change in debt composition happens along the intensive margin (relative share of loans to bonds) following the shocks.

[8] The specification of small versus large corporate finance firms is used for reasons of convenience. It serves to differentiate two types of firms based on their financing needs. Moreover, it replicates a general empirical finding that large corporations use, by and large, more capital market debt, whereas small firms use bank financing.

3.3.4 Bond financing

Large (corporate finance) firms,[9] which are equivalent to entrepreneurs in Bernanke et al. (1999), convert the raw capital into the effective capital and rent it to intermediate firms. The capital purchase is financed partly by the firm net worth, N_t^B, and partly by debt financing in the form of corporate bonds, B_t^B:

$$B_t^B \equiv Q_t^B K_t^B - N_t^B. \tag{3.14}$$

Large representative firm makes revenues by providing capital services to the intermediate producers and selling the non-depreciated capital to capital goods producers. Therefore, the ex-post returns on capital are given by:

$$R_{k,t+1}^B = \frac{r_{k,t+1}^B + (1-\delta)Q_{t+1}^B}{Q_t^B}, \tag{3.15}$$

where Q_t^B denotes the price of capital in the respective sector. The return on capital represents the ratio between the revenues coming from capital services (i.e., the rental rate of capital, $r_{k,t+1}^B$) and proceeds from selling the undepreciated capital and costs associated with the purchases of capital. Parameter $0 < \delta < 1$ denotes the depreciation rate.

Optimal bond contract

The debt contract between a large firm and a mutual fund follows a standard debt (bond) contract[10] as presented in Bernanke et al. (1999) and Christiano et al. (2010, 2014) (henceforth, CMR). An idiosyncratic shock ω_t^B affects each large firm and determines how much of the raw capital turns into effective capital. If $\omega_t^B > \bar{\omega}_t^B$, the lender receives the full payment, $Z_{t+1}^B B_t^B$, where Z_{t+1}^B is the agreed rate to be paid one period later. I assume that ω_t^B is log normally distributed with $E(\omega_t^B) = 1$ and $Var(\ln \omega_t^B) = \sigma_\omega{}^2$. All the distribution properties are included in the relevant definitions and equilibrium conditions in appendix B (for more details see, e.g., Bernanke et al., 1999). At the center of the model is the mutual fund's participation

[9]The superscript B refers to the variables associated with the representative large firm. It will be shown that all the firms within the sector are identical, which allows me to denote the aggregate variables related to the respective sector with the respective subscript.

[10]The maximization problem refers to a representative B-th large (corporate finance) firm in the B-sector; however, to simplify the notation, I will only use a "B"-superscript to refer to the variables related to the large/bond sector. After solving for the optimal contract, it can be shown that the solution does not depend on any individual characteristics of the firm and that all the firms in the respective sector are identical and symmetric.

constraint given by:

$$E_t \left\{ (1 - F_t(\bar{\omega}^B_{t+1}))Z^B_{t+1}B^B_t + (1 - \mu_{t+1}) \int_0^{\bar{\omega}^B_{t+1}} \omega^B dF_t(\omega^B) R^B_{k,t+1} Q^B_t K^B_t \right\}$$
$$\geq R_t B^B_t, \tag{3.16}$$

$F_t(\bar{\omega}^B_{t+1})$ is a cumulative distribution function (and the probability of default) of ω^B. On the LHS of equation (3.16) there are two components: the amount of corporate bonds that is paid back by the non-defaulting large firm and, in the default case, the acquisition of the large firm's remaining assets after paying monitoring costs, which is a linear function of the value of assets. The expected return from the debt contract must be equal to the return from a riskless asset (i.e., household deposits). The optimal contract for the representative large firm solves:

$$\max_{\{\bar{\omega}^B_{t+1}, K^B_t\}} E_t \left\{ \left[1 - \Gamma_t(\bar{\omega}^B_{t+1})\right] R^B_{k,t+1} Q^B_t K^B_t \right\} \tag{3.17}$$

$$\text{s.t.~} E_t \left\{ \left[\Gamma_t(\bar{\omega}^B_{t+1}) - \mu_{t+1} G_t(\bar{\omega}^B_{t+1})\right] R^B_{k,t+1} Q^B_t K^B_t \right\} = R_t(Q^B_t K^B_t - N^B_t), \tag{3.18}$$

Note that the objective function represents the share $1 - \Gamma_t(\cdot)$ of average large firm earnings obtained by large firms and the constraint is the rewritten participation constraint given in equation (3.16),[11] using the following definitions: $\Gamma_t(\bar{\omega}^B_{t+1}) \equiv (1 - F_t(\bar{\omega}^B_{t+1})\bar{\omega}^B_{t+1} + \int_0^{\bar{\omega}^B_{t+1}} \omega dF_t(\omega^B)$ and $G_t(\bar{\omega}^B_{t+1}) \equiv \int_0^{\bar{\omega}^B_{t+1}} \omega^B dF_t(\omega^B)$. $\Gamma_t(\cdot)$ and $\mu_{t+1}G_t(\cdot)$ denote respectively the share of large firm earnings received by the mutual fund and the expected monitoring costs. I allow for monitoring costs to be time-varying in order to model the change in the auditing ability of mutual funds. For example, an unexpected increase in monitoring costs makes the verification of the large firm's project outcomes costlier, i.e., the degree of asymmetric information between the mutual fund and the large firm worsens.

Combining the first order conditions, I obtain the relationship between the return on capital and bond finance premium, $E_t R^B_{k,t+1} = E_t[\rho(\bar{\omega}^B_{t+1})R_t]$, where $\rho(\bar{\omega}^B_{t+1}) = \frac{\Gamma'_t(\bar{\omega}^B_{t+1})}{[(\Gamma_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G_t(\bar{\omega}^B_{t+1}))\Gamma'_t(\bar{\omega}^B_{t+1}) + (1-\Gamma_t(\bar{\omega}^B_{t+1}))(\Gamma'_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G'_t(\bar{\omega}^B_{t+1}))]}$ represents the bond finance premium. The external finance premium represents a wedge between the cost of financing capital and costs of funds from the lender. In the absence of monitoring costs and the possibility of default ($F(\omega^B) \to 0$), $\rho \to 1$. With costly state verification in place, the monitoring arises to verify the success of firm's projects, implying $\rho > 1$.

Defining the leverage ratio $\phi^B = \frac{Q^B_t K^B_t}{N^B_t}$ and using the resource constraint, a relationship between the threshold productivity and the leverage ratio can be

[11]The market for corporate bonds is perfectly competitive, which implies that mutual funds make zero profits and the constraint holds with a strict equality. CMR state that the free entry ensures that the constraint is a strict equality.

written as:

$$\phi_t^B = 1 + E_t \left\{ \frac{\frac{\Gamma_t'(\bar{\omega}_{t+1}^B)}{(\Gamma_t'(\bar{\omega}_{t+1}^B) - \mu_t G_t'(\bar{\omega}_{t+1}^B))} (\Gamma_t(\bar{\omega}_{t+1}^B) - \mu_{t+1} G_t(\bar{\omega}_{t+1}^B))}{(1 - \Gamma_t(\bar{\omega}_{t+1}^B))} \right\}. \tag{3.19}$$

Therefore, there exists a one-for-one relationship between the leverage ratio and the external bond finance premium, $\phi^B = \phi(\rho)$. Each large firm chooses a combination of $(\bar{\omega}^B, K^B)$ or equivalently $(\bar{\omega}^B, \phi^B)$ to solve the maximization problem in (3.17). Since the initial net worth position does not affect the optimality condition, the leverage ratio is the same across firms in the bond sector and they pay the same bond finance premium.

Within one period, the large firm sells the undepreciated capital to capital producers, collects the proceeds from capital rented to the intermediate good producers and settles the debt obligation with the mutual fund. A random fraction $1 - \gamma^B$ of net worth is transferred to the household. The net worth of firm gets accumulated with the constant lump-sum transfers of households, W^B, and the remaining γ^B fraction of the share of large firm earnings:

$$N_t^B = \gamma^B (1 - \Gamma_{t-1}(\bar{\omega}_t)) R_{k,t}^B Q_{t-1}^B K_{t-1}^B + W^B. \tag{3.20}$$

3.3.5 Bank financing

As in Gertler and Karadi (2011), banks are depository institutions that channel funds from households to small firms.[12] In this process, they increase their net worth by earning return on loans, B_t^S,:

$$\begin{aligned} N_t^S &= R_{k,t}^S Q_{t-1}^S B_{t-1}^S - R_t D_{t-1}^S, \\ &= (R_{k,t}^S - R_t) Q_{t-1}^S B_{t-1}^S + R_t N_{t-1}^S, \end{aligned}$$

where Q_t^S the real price of the loan claim, N_t^S intermediary's equity capital and D_t^S denotes deposits the intermediary obtains from households. A moral hazard problem arises because the banker may divert the fraction λ_t^S of total assets back to his own family in form of large bonuses. The cost to the banker is that depositors can force the intermediary into bankruptcy and recover the remaining fraction $1 - \lambda_t^S$ of assets. For depositors to give funds to the banker, the following incentive constraint must hold:

$$V_t \geq \lambda_t^S Q_t^S B_t^S.$$

[12] Small firms or small corporate finance firms represent a veil, as they costlessly channel funds from banks to intermediate firms. There is no friction in this process. The financial friction arises in the relationship between banks and households.

Unlike Gertler and Karadi (2011), I assume that λ_t^S is time-varying. An unexpected banking shock resulting from an increase in distrust of the banking sector by depositors (see, e.g., Dedola et al., 2013) leads to an increase in λ_t^S. This makes the moral hazard problem worse, as it induces a reduction in funds managed by banks and subsequently credit tightening.

Following Gertler and Karadi (2011), banker's expected terminal wealth can be rewritten as:

$$V_t = \nu_t Q_t^S B_t^S + \eta_t^S N_t^S,$$

whereby

$$\begin{aligned} \nu_t &= E_t\left\{(1-\gamma^S)\beta\Lambda_{t,t+1}(R_{k,t+1}^S - R_{t+1}) + \beta\Lambda_{t,t+1}\gamma^S \chi_{t,t+1}, \nu_{t+1}\right\}, && (3.21)\\ \eta_t^S &= E_t\left\{(1-\gamma^S) + \beta\Lambda_{t,t+1}\gamma^S z_{t,t+1}\eta_{t+1}^S\right\}. && (3.22) \end{aligned}$$

The variable ν_t can be interpreted as the expected discounted marginal gain to the banker of expanding assets by a unit, holding net worth constant, while η_t^S is the expected discounted value of having another unit of net worth, holding assets constant. $\chi_{t,t+i} \equiv \frac{Q_{t+i}^S B_{t+i}^S}{Q_t^S B_t^S}$ and $z_{t,t+i} \equiv \frac{N_{t+i}^S}{N_t^S}$ denote growth rates of assets and net worth, respectively. Parameter γ^S is the survival probability of bankers.

Furthermore, the agency problem restricts the bank's leverage ratio to the point where the incentive to divert funds is exactly balanced by the costs of engaging in this activity. Hence, the amount of assets that the bank can manage will depend positively on its net worth as follows:

$$\begin{aligned} Q_t^S B_t^S &= \frac{\eta_t^S}{\lambda_t^S - \nu_t} N_t^S, && (3.23)\\ &= \phi_t^S N_t^S. && (3.24) \end{aligned}$$

A random fraction γ^S of bankers survive each period and accumulate their net worth based on revenues from bank operations. New bankers receive a start-up transfer from the household, $\omega^S Q_{t-1}^S B_{t-1}^S$. Thus, the net worth accumulation reads:

$$N_t^S = \gamma^S[(R_{k,t}^S - R_{t-1})\phi_{t-1} + R_{t-1}]N_{t-1}^S + \omega^S Q_{t-1}^S B_{t-1}^S, \qquad (3.25)$$

where $R_{k,t}^S - R_{t-1}$.[13] denotes the bank finance premium. Note that bank loans extended to small firms are used to finance their capital purchases:

$$Q_t K_t^S = Q_t B_t^S.$$

In contrast to the case of large firms, I do not specify further characteristics of small firms, such as a leverage ratio and the value of their assets. They represent a

[13] Gertler and Karadi (2011) name this term credit spread. For convenience and comparability to the bond sector, the spread is termed as the premium for bank finance.

veil that rents capital from capital producers, finances capital purchases by bank loans and makes the capital available to intermediate goods producers. As a result, the return on capital is analogous to the case of the large firm:

$$R^S_{k,t+1} = \frac{r^S_{k,t+1} + (1-\delta)Q^S_{t+1}}{Q^S_t}. \tag{3.26}$$

3.3.6 Capital goods firms

The investment decision is conducted by capital goods firms which are owned by households. As in the case of external financing, I differentiate between two types of capital goods producers - each one for providing physical capital of particular type j, with $j \in (S, B)$. In the perfectly competitive environment capital goods producers employ the undepreciated capital together with investment goods of type j to produce new capital of the same type. The old capital can be transformed costlessly into the new capital, whereas the convex adjustment costs are entailed in the conversion of the investment into new capital:

$$\begin{aligned}
&\max_{I^j_t} \quad E_t \sum_{t=0}^{\infty} \beta^{t+k} \Lambda_{t,t+k} \left[q^j_{t+k} \left(1 - f\left(\frac{I^j_{t+k}}{I^j_{t+k-1}}\right)\right) I^j_{t+k} - I^j_{t+k} \right] \\
&K^j_t = \left\{ (1-\delta)\, K^j_{t-1} + \left(1 - f\left(\frac{I^j_t}{I^j_{t-1}}\right)\right) I^j_t \right\},
\end{aligned}$$

with I^j_t denoting investment of type j, Q^j_t the real price of capital of type j. First order condition for optimal investment reads:

$$Q^j_t = \frac{1 - \beta E_t \left\{ \Lambda_{t,t+1} f'\left(\frac{I^j_{t+1}}{I^j_t}\right) \frac{{I^j_{t+1}}^2}{{I^j_t}^2} \right\}}{1 - f\left(\frac{I^j_t}{I^j_{t-1}}\right) - f'\left(\frac{I^j_t}{I^j_{t-1}}\right) \frac{I^j_t}{I^j_{t-1}}}. \tag{3.27}$$

Note that $f\left(\frac{I^j_t}{I^j_{t-1}}\right) = \frac{\xi^j}{2}\left(\frac{I^j_t}{I^j_{t-1}} - 1\right)^2$. Parameter ξ^j measures the degree of curvature of investment adjustment cost.

3.3.7 Monetary policy and resource constraint

The central bank sets the nominal interest rate according to the following Taylor-type policy rule:

$$\frac{R^n_t}{R^n} = \left(\frac{R^n_{t-1}}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)} \varepsilon^{MP}_t, \tag{3.28}$$

where R^n and π denote the steady-state values for nominal interest rate and inflation, R_t^n and π_t, respectively. ε_t^{MP} is an unexpected monetary policy shock. The parameter α_π is the weight on inflation, ρ_r measures the degree of the interest rate smoothing. Note also that the Fisher relation holds, i.e., $R_t = \frac{R_t^n}{E_t \Pi_{t+1}}$.To complete the model, the aggregate resource constraint is given by:

$$Y_t = C_t + I_t,$$

where the aggregate investment is given by $I_t = \eta I_t^S + (1-\eta) I_t^B$. The rental market for capital and labor market, the market for bonds and bank loans clear implying:

$$\int_0^\infty K_{i,t}^S di = K_t^{S,a} = \eta K_t^S, \tag{3.29}$$

$$\int_0^\infty K_{i,t}^S di = K_t^{B,a} = (1-\eta) K_t^B, \tag{3.30}$$

$$B_t^{tot} = B_t^{tot,B} + B_t^{tot,S}, \tag{3.31}$$

where B_t^{tot} represents total credit, $B_t^{tot,S} \equiv \eta Q_t^S B_t^S$ and $B_t^{tot,B} \equiv (1-\eta)(Q_t^B K_t^B - N_t^B)$ total values of bank loans and corporate bonds, respectively. I define the bank loans' share, Υ_t, as the ratio of bank loans and corporate bonds:

$$\Upsilon_t = \frac{B_t^{tot,S}}{B_t^{tot,B}}. \tag{3.32}$$

Finally, the goods market clearing requires that the total aggregate demand equals total aggregate production:

$$Y_t = A_t (K_t)^\alpha (L_t)^{1-\alpha}. \tag{3.33}$$

The shocks follow autoregressive processes given by:

$$\ln A_t = \rho_a \ln A_{t-1} + e_{t,A}, \tag{3.34}$$

$$\ln \lambda_t^S = (1-\rho_G) \ln \lambda^S + \rho_G \ln \lambda_{t-1}^S + e_{t,S}, \tag{3.35}$$

$$\mu_t = \frac{1}{1+e^{\Xi_t}}, \tag{3.36}$$

$$\ln \Xi_t = (1-\rho_G) \ln \Xi + \rho_G \ln \Xi_{t-1} + e_{t,B}, \tag{3.37}$$

where $\rho_A, \rho_G \in (0,1)$ and $e_{t,x}, \sim iid(0, \sigma_x^2)$, whereby $x = \{A, S, B\}$. $e_{t,S}$ and $e_{t,B}$ denote, respectively, shocks in the banking and bond sector. The specification of the bond sector shock ensures that monitoring costs μ_t falls between 0 and 1, as suggested by Fuentes-Albero (2014). In the following, I consider the banking shock and the economy-wide financial shock, which is a combination of shocks originating in both sectors. λ^S and Ξ represent the steady state values of λ_t^S and Ξ_t.

3.4 Results

3.4.1 Calibration

The time unit is one quarter. The calibration of two sector corporate debt market matches the characteristics of the US economy and it is presented in table 3.1. Standard model parameters are calibrated in the vein of Gertler and Karadi (2011). The discount factor β is calibrated to 0.99. In the household utility function ψ_L is chosen so that steady-state working hours are one third, whereas ϕ_L, the inverse of the labor supply elasticity, is set to 0.276. The labor share, $1-\alpha$, is 0.33. The depreciation rate δ is set at 2.5 percent. In the intermediate goods sector, the degree of monopolistic competition ε is calibrated at 4.167. The Calvo parameter θ giving the probability that a firm does not change price is calibrated at 0.779. which implies that prices in the economy are adjusted every four and a half quarters on average. The degree of price indexation, ι, is 0.241. As far as monetary policy is concerned, the autoregressive parameter, ρ_r, is set to 0.8 and the coefficient on inflation rate, α_π, to 1.5. I follow Gertler and Karadi (2011) and set the curvature of investment adjustment cost for both type of capital goods producers, ξ^j, to 1.728. The degree of substitutability between the two types of capital services, ρ, is set to 0.6, which is taken from Verona et al. (2013).

Table 3.1: Calibration

Parameter	Value	Description	Target
η	0.263	share of small firms	$\frac{Loans}{Bonds} = 0.66$
γ_S	0.957	survival probability of banker	Leverage: 4
γ_B	0.979	survival probability of large firms	Leverage: 2
λ^S	0.609	fraction of divertible bank capital	258bp.(annualized)
μ	0.079	monitoring cost (mutual funds)	BBB-spread: 209bp.(annualised)
$F(\omega^B)$	0.0134	default probability	SG-debt: 5.37% (annualised)
W^B	0.005	transfer from households	Christiano et al. (2014)
ω^S	0.002	transfer from households	Gertler and Karadi (2011)

The parameters related to the financial sector presented in table 3.1 deserve some further attention. The share of firms that use bank financing, η, is set so that, the ratio of bank to bond financing in the US is exactly matched (0.66). The value is reported by DeFiore and Uhlig (2011). To obtain the bond finance premium, I use the spread for BBB-rated corporate debt (relative to the spot Treasury curve).[14] I calculate the bank finance premium as the difference between the lending rate on commercial and industrial loans with moderate risk and the Treasury yield (with comparable maturity). The annualized premium for bank loans (258 basis points) is slightly higher than the premium for bond finance (209 basis points). Note that DeFiore and Uhlig (2011) also report that the loan spread is higher than the bond spread in the US data. Following Bernanke et al. (1999), I calibrate the leverage ratios (the ratio of total assets to equity) to 2 for the firm sector using bond financing, whereas the bank leverage is calibrated to 4, as in Gertler and Karadi (2011), who argue that the corporate sector is less leveraged than the financial sector. Together with the premia, the leverage ratios are used to pin down respectively the survival probabilities of large firms and bankers, γ_S and γ_B. The default probability $F(\omega^B)$ is set to match the default rate on the US speculative grade debt (similar to DeFiore and Uhlig, 2011). The idiosyncratic shocks ω^B follow the log-normal distribution with $E\omega^B = 1$. Evaluating the optimality conditions of large firms in the steady state, I obtain a value for μ^B of 0.079 which is smaller than the value of 0.19 reported by Bernanke et al. (1999). A smaller calibrated parameter reflects a less severe asymmetric information problem between mutual funds and large firms, as the former incur lower costs to recover large firms' returns. Note that both the steady state value of λ of 0.609 and the banker's survival probability of 0.957 differ from the proposed values by Gertler and Karadi (2011). This comes as a result of the higher bank premia I used to match the data on bank loans. The steady state values of transfers from households to the large firm and the banking sector, W^B and ω^S, are set to 0.005 and 0.002, based on Christiano et al. (2014) and Gertler and Karadi (2011).

Regarding the calibration of shock processes, I specify the standard deviation of shocks so that the estimated output responses from the SVAR, presented in section 3.2, are exactly matched on impact following aggregate supply and financial shocks in the third chapter. The persistence parameter is set so that the theoretical response of output falls within the estimated credible set. The impulse response matching leads to the following values of parameters: $\rho_A = 0.70$, $\rho_G = 0.70$, $\sigma_A = 0.012$ and $\sigma_S, \sigma_B = 0.067$. For the economy-wide financial shock, the standard deviation is chosen to replicate a rise in both bank and bond premia, in addition to matching the response of output on impact.[15]

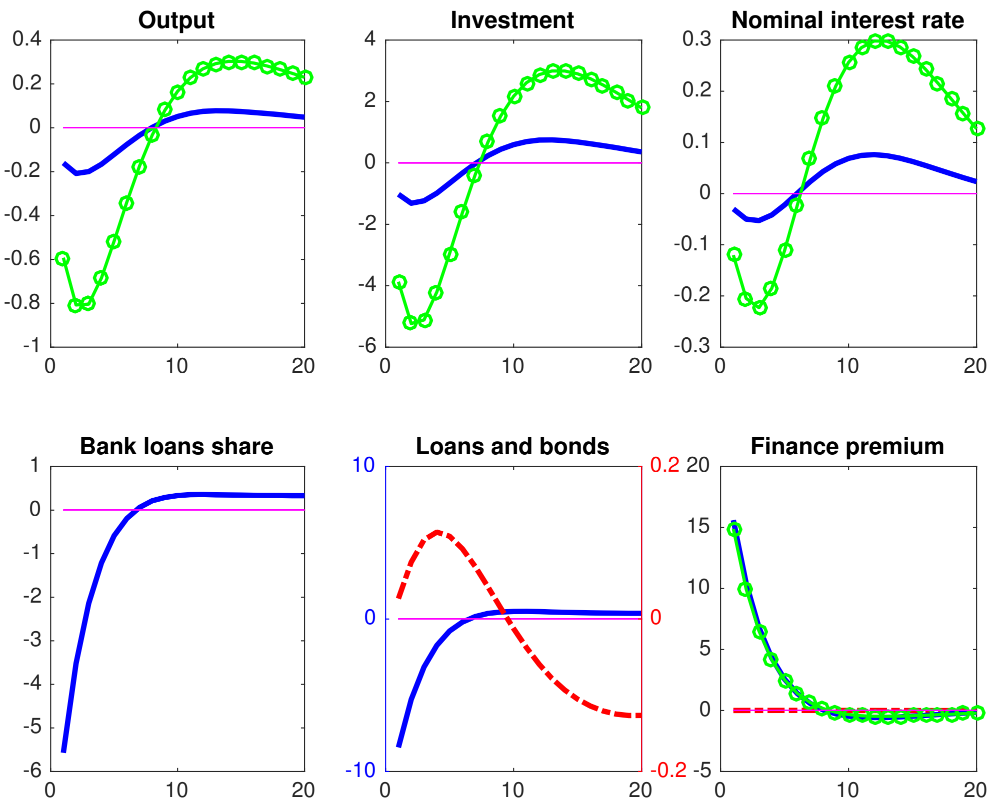
[14]Note that I assume that a representative US corporate bond security is characterized by BBB investment grade debt. For example, Denis and Mihov (2003) report that BBB is the median new debt rating.

[15]The calibrated shock generates a rise in finance premia, that corresponds to the lower bound of the credible set of the estimated financial shock, documented in figure B.2. In order to match the estimated empirical spread for capital market finance, I assume that the shock to monitoring costs is five times stronger than the shock to the banking sector.

3.4.2 Model comparison: Does debt composition matter?

To understand how corporate debt financing affects the propagation of the shocks, I compare the model economy with both bond and bank markets (benchmark case) with an economy relying only on bank credit.[16] Do differences in the composition of aggregate corporate debt play a role for the real economy? To conduct these experiments, I set the share of bond sector to 0, which results in one source of capital and one financial (banking) sector. I also consider an economy without financial frictions. I assume that all the model economies are hit by a shock process of the same size.

Figure 3.3: Adverse banking shock



Note: Green circled lines refer to the dynamics of model economy with the banking sector, whereas blue lines refer to the benchmark model economy. Red lines denote bond-sector specific variables, while blue dashed lines denote the bank-specific variables in the benchmark economy. Label "Benchmark" and "Only Banks" refer, respectively, to the benchmark model presented in section 3.3 and the model with the banking sector. Nominal interest rate, bank loans share and finance premia are reported in absolute deviations, the remaining variables are expressed in percentage deviations. Interest rates and premia are reported in annualized terms. Horizontal axes display quarters after the shock.

[16] The alternative exercise can refer to the comparison of an economy with a stronger reliance on bank credit (European-type economy) to an economy with a predominance of capital market debt (US). The calibrated value for the ratio of bank loans and bonds can be adjusted, so that it reflects the debt composition (aggregate bank loans and corporate bonds) in Europe. The European-type model economy would fall in between the two model economies considered above.

Figure 3.3 displays the responses of the two model economies with financial markets to the banking shock. It is a rather simple way to proxy for a negative financial shock that can be a result of a confidence loss in the banking sector (as described by Dedola et al., 2013) and leads to tightening in lending standards. The shock increases the incentive of bankers to divert assets which makes their leverage constraint tighter. Banks reduce the amount of intermediated loans for a given value of net worth. Under these circumstances of the disruption in bank intermediation, finance premia on loans need to increase to make bank operations profitable. The propagation of the banking shock is effective mainly through the bank-lending channel. As small firms are only dependent on bank finance, they curtail their investment spending as a result of loan supply restrictions. Lower capital demand leads to a decline in the price of capital and investment of firms dependent on bank financing, which results in a decline of real output.

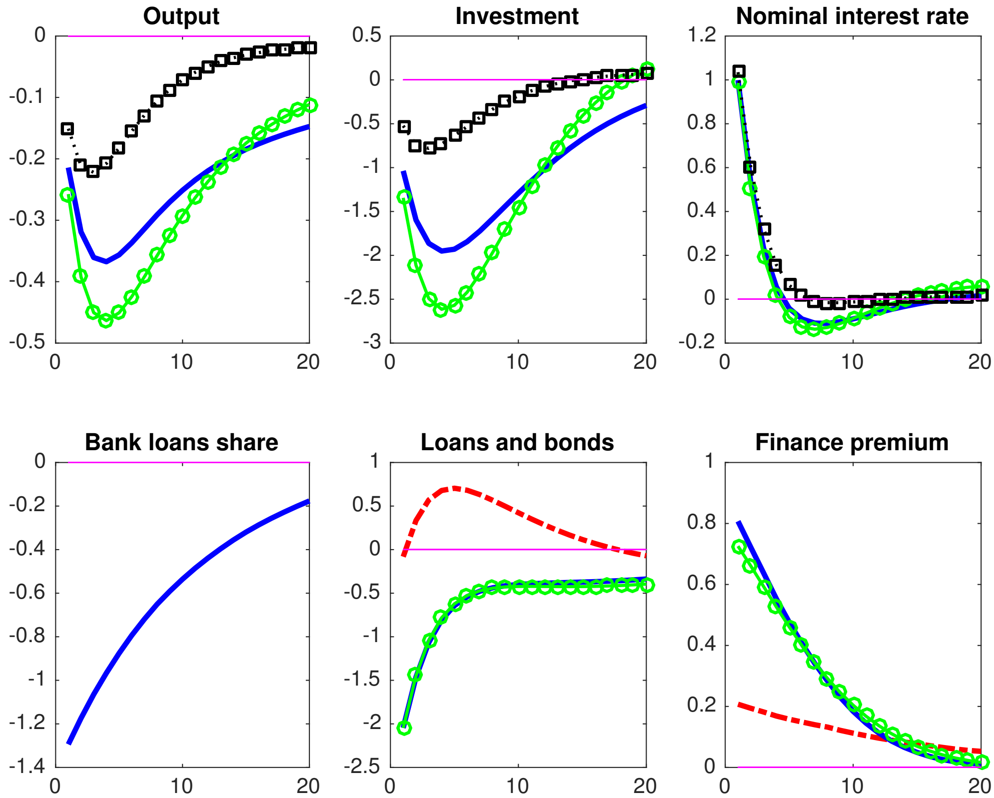
The adverse banking shock affects only the banking sector and leads to a substantial rise in bank finance premia (by the same amount in both economies) and no change in the premium for bond finance. The reason is that the bond market is not affected by the banking shock, i.e., the determinants of the bond finance premia (the leverage ratio of large firms and the default threshold) remain unchanged.

Real output and investment in the banking sector economy fall more than three times as much as in the benchmark model. The reactions of output and investment are attenuated in the benchmark model economy, as there is a stronger substitution along the intensive margin from loans to bonds (c.f., a decline in the loan-to-bond ratio in figure 3.3). This credit market development following the negative banking shock in the benchmark model nicely represents the changes in the debt composition in figure B.1 reported by Adrian et al. (2012).

It might not be surprising that the tightening of bank credit standards, which is reflected in the tightening of banks' incentive constraints, results in stronger real effects in the banking model economy. Nonetheless, it is worth mentioning that this finding is in line with the empirical evidence by Gambetti and Musso (2017). The authors document that the real short-term effects of loan supply shocks are stronger in Europe than in the US. Their loan supply shock, identified by an increase in the lending rate and a decline in the credit volume on impact in their SVAR, is consistent with the initial reactions of respective variables in my theoretical setup.

It is interesting to note that the composition of corporate debt helps to mitigate the negative effects of the financial shock. As the sector dependent on bond finance is not affected by the shock, large firms can issue bonds to finance their purchases of capital. As a result, there is little change in their investment spending. For this reason, a decline in the aggregate investment is mostly due to the reductions in investment spending of small firms using bank finance (to be shown in figure 3.6).

Figure 3.4: Adverse monetary policy shock



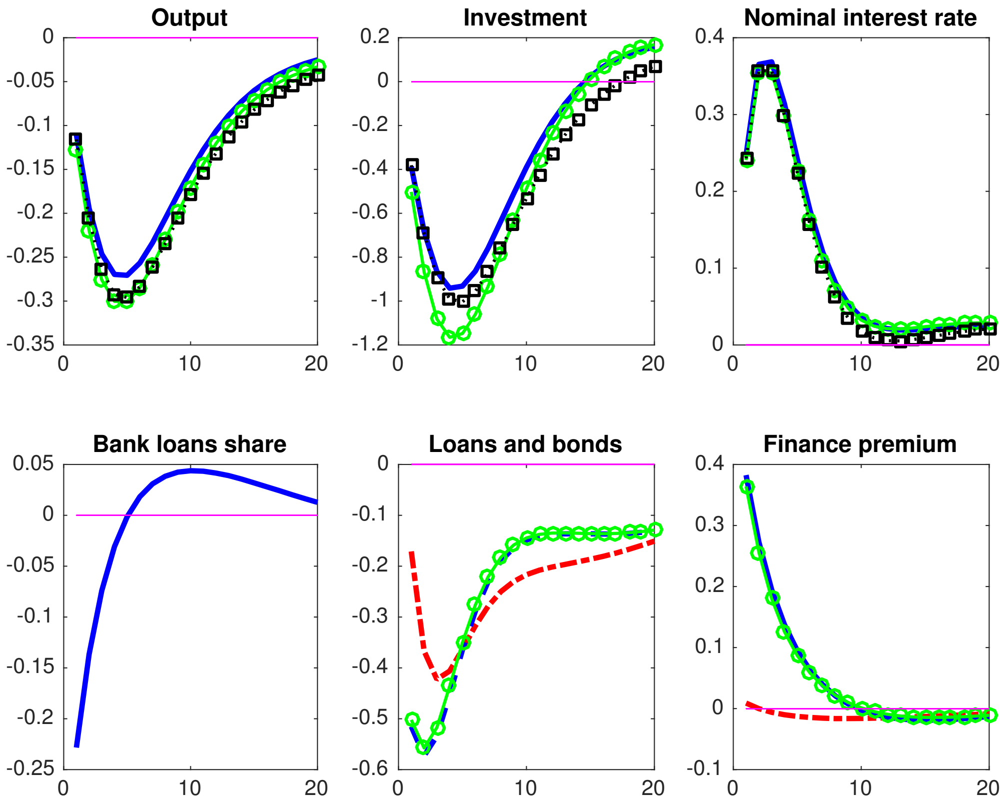
Note: Green circled lines refer to the dynamics of model economy with the banking sector labeled "Only Banks", whereas black lines with squares refer to the model economy without financial frictions labeled "NoFF". Blue lines refer to the benchmark model economy labeled "Benchmark". Red dashed lines denote bond-sector specific variables, while blue lines denote the bank-specific variables in the benchmark economy. Nominal interest rate, bank loans share and finance premia are reported in absolute deviations, the remaining variables are expressed in percentage deviations. Interest rates and premia are reported in annualized terms. The adverse shock corresponds to one percentage point increase in the nominal interest rate.

The short-lived reaction of the aggregate investment matches well my empirical impulse response functions presented in figure B.2. The theoretical model predicts a stronger decline in the bank loans' share than the one in empirical counterpart. Overall, the model does well in mimicking the empirical dynamics of investment, nominal interest rate and spreads.

Figure 3.3 also highlights a recovery in the banking sector in both economies. In the context of high bank finance premia, banks' profitability improves rapidly and trust in the banking system is restored. As a consequence, banks' balance sheet conditions stabilize and banks are willing to extend loans to small firms.

Figure 3.4 depicts the dynamics of key financial and aggregate variables in the benchmark model, the model with only a banking sector and the model without financial frictions following a contractionary monetary policy shock (one percentage point increase in the nominal interest rate). First, as has been emphasized before in the literature,[17] the presence of financial frictions exacerbates the negative effects of monetary policy shocks by intensifying their effects on investment and the price of capital. Second, leveraged banks reduce credit lines to small firms in order to meet their capital requirements, which leads to a substantial decline in investment and output in the bank-dependent sector. On the other hand, the rise in bond issuance, which is extended to large firms via mutual funds, enables these firms not to divest as strongly as the small firm sector dependent on bank financing. As a result, the reactions of investment and output are attenuated in the benchmark economy. Mutual funds do not need to fulfil any capital requirements, and, therefore, are willing to provide bond financing in return for high bond premia.

Figure 3.5: Adverse technology shock



Note: Green circled lines refer to the dynamics of model economy with the banking sector labeled "Only Banks", whereas black lines with squares refer to the model economy without financial frictions labeled "NoFF". Blue lines refer to the benchmark model economy labeled "Benchmark". Red dashed lines denote bond-sector specific variables, while blue lines denote the bank-specific variables in the benchmark economy. Nominal interest rate, bank loans share and finance premia are reported in absolute deviations, the remaining variables are expressed in percentage deviations. Interest rates and premia are reported in annualized terms.

The dynamic consequences of a technology shock are shown in figure 3.5. The initial development of the loan-to-bond ratio and the propagation of a technology

[17]See, for example, Gerali et al. (2010) and Gertler and Karadi (2011) among others.

shock with respect to investment matches well my empirical evidence on aggregate supply shocks reported in figure B.3. The technology shock affects mainly the production capability of the intermediate goods producers, who reduce capital demand in the face of lower productivity. This induces a fall in external financing, with slight differences between the sectors and two different model economies. As the needs for external financing in the bond and banking sector develop similarly, the debt composition changes only slightly and does not matter for real output.[18]

Note that the changes in finance premia following the technology shock are much smaller than the largest response of finance premia in the banking shock scenario. Similarly, the other financial variables are much less sensitive to the technology shock. Therefore, the propagation of the shock through the financial sector is rather negligible. Over time, banks reduce provision of loans relatively less compared to the bond issuance volumes, which can be seen in the increase of the loan-to-bond ratio, i.e., the bank loans' share.

3.4.3 Inspecting the mechanism: Financial and monetary policy shocks

In order to better understand the role of variation in the corporate debt composition (as a result of an increase in bond issuance), I examine further monetary and financial shocks. Figure 3.6 displays the impulse responses of some key real and financial variables to an adverse financial shock affecting the bank and bond market simultaneously in the benchmark economy. In particular, this financial shock leads to an increase in distrust of the banking sector and a tightening of monitoring standards by mutual funds. The reason for this specification is to match my SVAR evidence with respect to increases in the premium for bank debt and non-bank debt.[19]

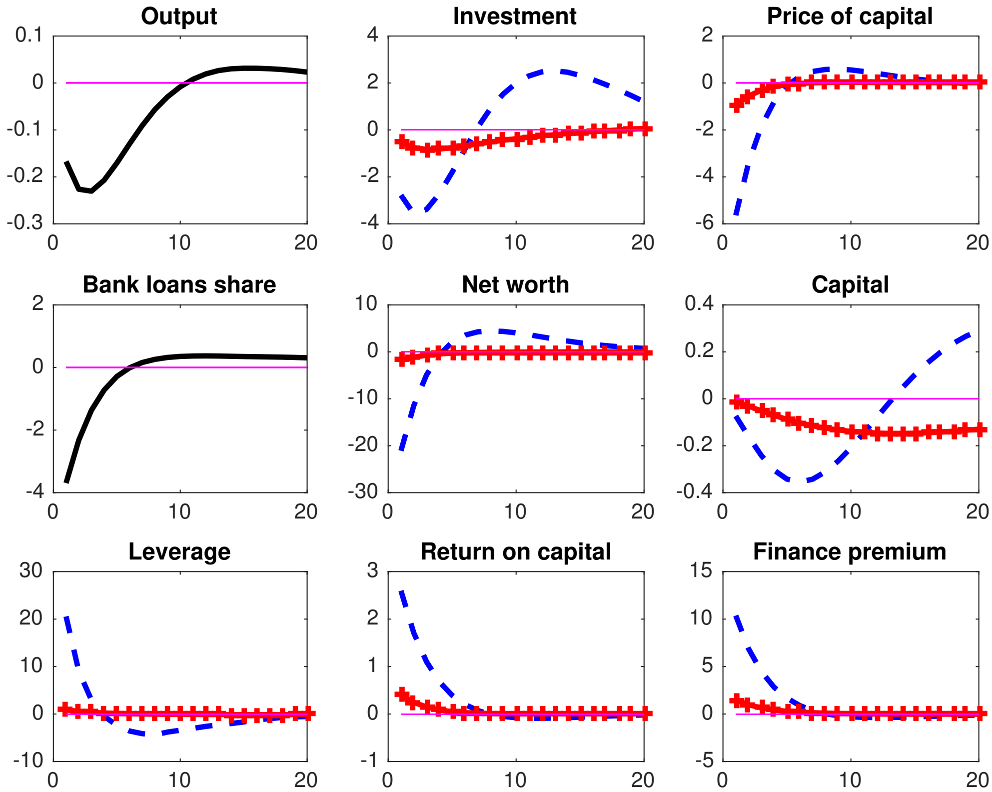
The dynamic effects of the financial shock on investment, output and debt-related variables match very well their empirical counterparts presented in figure B.2. Note that the model replicates the rebound in investment documented in the SVAR model together with the development of bank and non-bank premia. It generates a stronger decline in the share of bank to bond finance than the one in the data (see figure B.2 in appendix B). The impulse response of most endogenous variables closely track their empirical counterparts during the considered period.

The unexpected confidence loss in the banking sector makes banks' balance

[18] The effects of the technology shock shock in the benchmark economy are discussed in appendix B. For completeness, I also comment on demand shocks modeled as preference shocks.

[19] Both banking shock and combined financial shock result in a disproportionate rise in the premium for the bank debt relative to the non-bank debt, as documented in the SVAR evidence. The specification of a combined financial shock generates additionally a rise in the bond finance premium.

Figure 3.6: Adverse financial shock



Note: Blue dashed lines refer to the variables associated with the banking sector, whereas the red circled lines refer to the bond sector. Black lines refer to the aggregates. Finance premia and the bank loans share are reported in absolute deviations, the remaining variables are expressed in percentage deviations.

sheets deteriorate, reducing the amount of the intermediated credit and banks' net worth. Banks start the process of de-leveraging, which comes to an end after five periods. The bank lending channel highlights the role of bank loan supply for small firms' investments. As small firms are only dependent on bank finance, they reduce their investments in the presence of restricted loan supply and a falling price of capital. The decline in the price of capital[20] leads to a rise in the expected return on capital in small firms. The buildup of capital and the rebound in the price of capital is associated with the higher investment demand after ten periods, which is then financed through recapitalized banks.

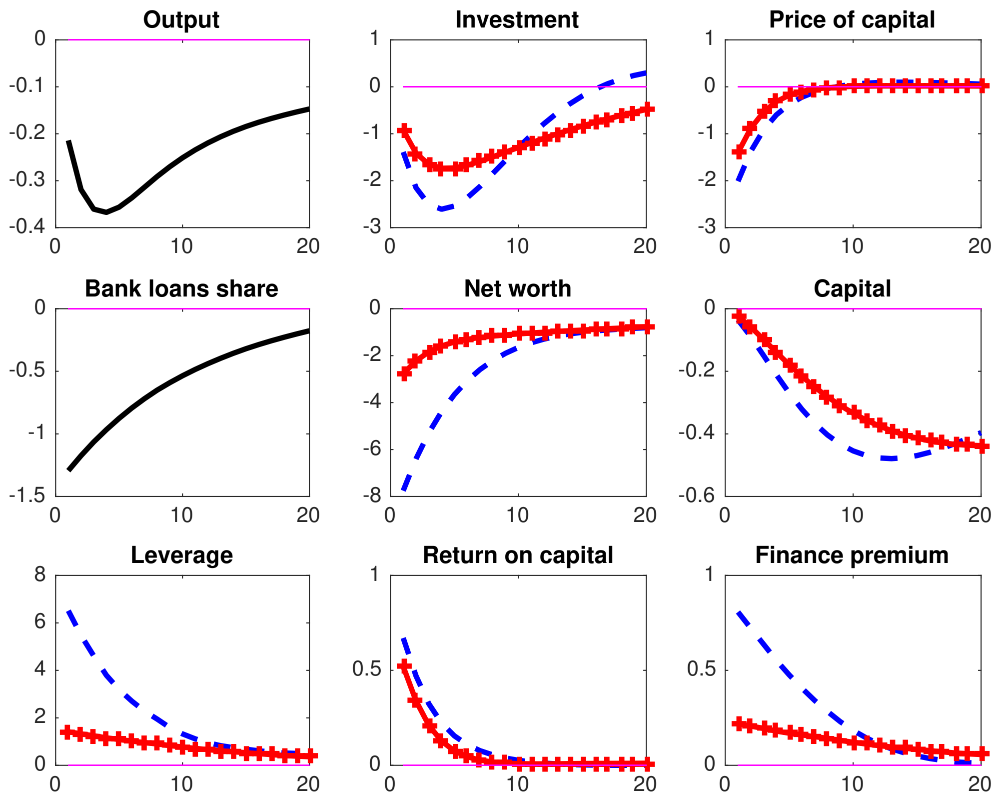
Interestingly, the model predicts a fast recovery of the banking sector. The reason is that banks can rather quickly restore their profitability by charging high loan premia. As a consequence, banks stabilize their balance sheet positions and start extending loans to firms. Once the banks are capitalized, they intermediate loans that the small firm sector uses for financing capital purchases.

There is a substitution towards the cheaper source of financing (bond financing).

[20]The financial shock gives rise to the financial-accelerator mechanism first explained by Bernanke et al. (1999), because the decline in investment decreases the asset price, further decreasing the firm's net worth and investment.

The finance premium on bonds is affected slightly due to an unexpected rise in monitoring costs by mutual funds; large firms' leverage and net worth change negligibly. Slightly leveraged large firms are able to obtain bond financing, as unconstrained mutual funds underwrite bond contracts in return for an increased finance premium. Given rather good financial positions, large firms can provide the necessary financing of physical capital, and, therefore, there is an increase in bond issuance. It follows that the investment of the large firm sector changes by little. At the production level, there is also a substitution towards the cheaper source of capital. As a result of small changes in the prices of capital and the capital demand, the investment spending of large firms is not altered very much.

Figure 3.7: Adverse monetary policy shock



Note: Blue dashed lines refer to the variables associated with the banking sector, whereas the red circled lines refer to the bond sector. Black lines refer to the aggregates. Finance premia and the bank loans share are reported in absolute deviations, the remaining variables are expressed in percentage deviations.

Figure 3.7 presents the responses of key variables in the benchmark model following a negative monetary policy shock. An unexpected increase in the policy rate leads to a decline in the aggregate demand. The lower demand for goods and capital depresses inflation and the price of capital. The decline in capital prices decreases large firms' and banks' net worth, which worsens their balance sheet positions and leads to a higher leverage. As a result, both finance premia increase after a contractionary monetary policy shock.

The reactions of most sector-specific variables are very similar; however, bank premia do increase more than bond premia which leads to a relatively smaller decline in investment by firms using bond financing. The relative decline in the ratio of loans to bonds indicates that the corporate debt composition changes in favor of bonds following monetary policy shocks, and, therefore, the model matches well the SVAR evidence by Kashyap et al. (1996) and Oliner and Rudebusch (1996).

The decline in the loan-to-bond ratio comes as a result of different dynamics of the two sectors. Bond issuance increases in order to fill in the gap between the purchases of capital and the net worth of large firms. The contractionary monetary shock causes the default threshold for these firms to rise, which makes the bond financing more expensive, as depicted by a rise in the bond finance premium. The optimal debt contract implies that higher bond issuance comes hand in hand with higher finance premia. The capital market channel highlights the role of bond finance premia in the provision of external financing. Unconstrained mutual funds are accordingly compensated for default risks of leveraged large firms. On the other hand, banks find that their balance sheets shrink as a result of lower prices of capital. The net worth of bankers is also negatively affected, which implies a tighter leverage constraint and a reduction in the intermediate funds. The higher bank leverage calls for an increase in the finance premium on loans. Investments conducted by the small firm sector is affected more as a result of banks' leverage constraints and higher loan premia.

The model shows that the transmission of monetary policy shocks, as depicted in figure 3.7, is altered if the heterogeneity of sectors relying on different types of financing is considered. The propagation of the shock through the bank-lending channel has already been documented in the literature (see, e.g., Gertler and Karadi, 2011). My model setup highlights the attenuating role of the capital market finance channel, and, hence, the relevance of the corporate debt composition.

3.5 Conclusion

The Great Recession featured a surge in corporate bond issuance and a decline in bank loans in the US, which indicates that the corporate debt composition changes over the business cycle (c.f., Adrian et al., 2012). This work addresses the relevance of the corporate debt composition for the aggregate economy in the following manner: First, I provide new empirical evidence on the dynamics of output, investment, the corporate debt composition and premia on the bank and non-bank debt. Second, I develop a DSGE model with bond and loan financing which succeeds in matching my SVAR evidence on real investment spending following financial and supply shocks and the evidence on monetary policy shocks by Kashyap et al.

(1996). Third, I consider different model economies in order to understand the role of the corporate debt composition in the propagation of economic shocks.

My empirical results highlight different conditional dynamics of corporate debt. In particular, the corporate debt composition reacts strongly to financial shocks, while at the same time the reaction of investment is short-lived. Estimated aggregate demand and supply shocks generate a persistent decline in investment and a persistent variation in corporate debt. The proposed DSGE model replicates well the dynamics of investment and the corporate debt composition following financial and macroeconomic shocks.

To what extent does the debt composition matter for output and investment? To understand how the availability of bank and bond finance affects the propagation of shocks, I compare an economy with both a bond market and a banking sector (benchmark economy) to an economy relying only on bank credit. The results indicate that access to bond financing reduces the negative effects of adverse financial and monetary policy shocks on the real economy. The intuition is the following: Shocks which affect bank's balance sheets in an adverse way lead to a reduction in funds intermediated by banks and a rise in bank finance premia. The reason is that leveraged banks have to comply with capital requirements. The bank lending channel highlights how the unavailability of bank loans for small firms adversely affects the investment spending of these firms. Mutual funds, which are not subject to any leverage constraints, are willing to underwrite bonds in return for higher bond finance premia. The effective capital market channel exemplifies the financing channel of large firms, which attenuates the effects of contractionary shocks on the investment of large firms. The interplay of the bank lending and capital market channels leads to the cyclical variation in the aggregate corporate debt composition. This is relevant for the propagation of financial and monetary shocks in the economy because the sector dependent on bank finance reduces investment much more than the sector dependent on bond finance. The model suggests the change in corporate debt composition (i.e., capital market finance) can help absorb some business cycle fluctuations. If bank credit is the only source of external finance, real investment and output are affected more than in the case of the benchmark economy. This result is in line with the empirical findings by Gambetti and Musso (2017), who document a stronger short-term real effect of loan supply shocks in Europe than in the US.

This paper offers one theoretical explanation for the empirical evidence on the corporate debt dynamics. It highlights the role of the bank lending and capital market channels in the cyclical variations in corporate debt and its repercussions for investment spending of firms. Furthermore, the aspects associated with the richer heterogeneity of corporate debt, policy actions aimed at improving lending conditions or the availability of capital market finance are not considered here. This extensions is a part of the following chapter.

Chapter 4

An optimal policy mix for segmented credit markets

Abstract

This paper analyzes welfare-improving central bank's policy rules within the context of a medium-scale DSGE model with a banking and a bond credit market in the presence of economy-wide and sectoral shocks. A combination of a Taylor policy rule, an unconventional bank credit policy and a bond-sector macroprudential tool stabilizes the macroeconomy and attains the highest level of welfare in the economy where both credit markets are affected by financial shocks. The main reason is that non-standard policies are effective at dampening the financial cycle, improving credit conditions and, even providing an additional stimulus to the economy. The welfare gains dissipate if shocks do not originate in the financial sector. If the central bank cannot correctly identify a sector-specific financial shock, and follows the policy mix conditional on economy-wide financial shocks, the level of welfare is comparable to the one under the optimal policy. However, welfare gains of optimized policies over the simple Taylor rule depends on the source of sectoral shock.

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4.1 Introduction

The conduct of central banks' monetary policy has changed substantially in the aftermath of the financial crisis starting in 2008. Central banks all around the world implemented different unconventional monetary policy measures[1] to tackle

[1]See, c.f., the review of unconventional measures by Borio and Zabai (2016). All major central banks, e.g., Federal Reserve, European Central Bank, Bank of Japan adjusted their balance sheets

disruptions in the financial sector. To address possible future risks emanating from the financial system, central banks have established macroprudential frameworks[2] to maintain and pursue financial stability. Both sets of these measures imply that central banks extended their spectrum of policy tools. What is the optimal choice of the central bank's policy instruments to help the economy's response to aggregate fluctuations?

In a seminal paper by Cúrdia and Woodford (2011), the authors conclude that the use of unconventional policy instruments should be tailored to conditions specific to disrupted financial markets. Motivated by the importance of influencing conditions in financial market segments with the appropriate policy, I analyze an interaction between interest rate policy and two different credit policy instruments in a financial DSGE model. The financial sector consists of a bond market, where mutual funds make bond financing available to large firms, and a banking market, where banks supply loans to small firms.[3]

This analysis of the central bank's optimal policy setup tries to merge two strands of literature: the rich literature on optimal monetary and credit policy instruments, and the emerging literature on macroprudential frameworks.[4] In my theoretical model, two credit policy instruments are designed to respond to credit imbalances in the respective credit market segment. They are specified as follows: The unconventional bank policy instrument is inversely related to bank lending activities and, therefore, represents a form of state intervention in the banking sector, similar to the modeling of the policy in Gertler and Karadi (2011). The central bank can support private credit flows to small firms, but the public intermediation is less efficient than bank intermediation. The bond policy instrument, modeled along the lines of Kannan et al. (2012), is a countercyclical macroprudential tool that affects directly funding costs of large firms and dampens credit fluctuations in the bond sector. The standard monetary policy instrument is a Taylor-type policy rule[5] for the nominal interest rate. The sources of business cycles are technology shocks and financial shocks. I differentiate between economy-wide and sectoral financial

in order to influence financial conditions. One dimension of these balance sheet policies is credit policy - operations that target private debt, banks and securities markets.

[2]Macroprudential policies are aimed at closely monitoring developments in financial markets and promptly reacting to possible financial imbalances in the form of asset price bubbles or excessive credit buildups. For example, the Bank of England, unlike the Federal Reserve, in the US, has the authority to conduct macroprudential policy (c.f., Gelain and Ilbas, 2017).

[3]The model setup is developed in the third chapter. The reliance of large firms on the bond market and small firms on banks is meant to capture the empirical finding by Colla et al. (2013) on the debt specialization of large and small US firms.

[4]In the context of DSGE models with one financial (credit) market, see the analysis of optimal credit policy in Cúrdia and Woodford (2011), Gertler and Karadi (2011) and Gertler et al. (2012) among others; for welfare implications of macroprudential policies, see Gelain and Ilbas (2017) and Bailliu et al. (2015). Note that there are numerous studies addressing the interaction of these policies in the context of housing market (e.g., Kannan et al., 2012; Quint and Rabanal, 2014) or open economy (e.g., Dedola et al., 2013; Brzoza-Brzezina et al., 2015).

[5]These rules have a good empirical fit (see Taylor, 1993).

shocks. Bank sector shocks emanate from a (dis)trust in banks, whereas bond sector shocks change auditing costs by mutual funds. The economy-wide financial shock is a combination of both sectoral shocks. I perform a welfare comparison of the simple Taylor rule, the optimized Taylor rule and the policy mix of credit policy and interest rate policy instruments.

My model featuring a segmented financial market can replicate the results from the previous literature on non-standard policy measures in the context of one single financial market (see, e.g., Cúrdia and Woodford, 2010; Bailliu et al., 2015; Gertler and Karadi, 2011; Cúrdia and Woodford, 2011). The key results on economy-wide shocks can be summarized as follows: First, the highest welfare gain of the combined credit and interest rate policies over the simple (optimal) Taylor rule is achieved if the economy is affected by economy-wide financial shocks. By addressing a particular credit market segment, these non-standard policies are effective at dampening the financial cycle, improving credit conditions and even providing an additional stimulus to the economy. Second, if the policy maker does not implement the mix of all three policy instruments, my model predicts that welfare losses are limited in the presence of technology shocks. The reason is that non-financial shocks do not cause substantial disruptions in respective credit market segments, so that there are no large benefits from the non-standard policies. Third, of the three policy designs that are being compared, my optimized policy mix achieves an outcome closest to the Ramsey optimal policy.

I make several contributions to the literature in the context of sectoral financial shocks. First, if the policy marker wrongly identifies a sector-specific financial disturbance, acting upon economy-wide financial shocks attains virtually the same level of welfare as the optimal policy mix. The intuition for this result is the following: The propagation of bank sector shocks resembles the model economy dynamics following economy-wide shocks (in terms of large disruptions in bank lending and a substantial rise in bank premia) and, therefore, the optimized policy in the economy affected by the latter shocks performs well also in the economy with bank sector shocks. In the presence of bond sector shocks both optimal and non-optimal policies cannot accommodate the effects of these shocks, yielding comparable welfare results. Second, I find that the source of sectoral financial disturbance matters. In the context of my model, high welfare losses arise irrespectively of the policy setting if the economy is affected by shocks originating in the bond sector. In particular, the optimal combination of unconventional policy tools does not compress a rise in bond premia, and therefore, does not offset disruptions in the bond market.

The remainder of the paper is organized as follows. Section 2 describes the model setup. Section 3 discusses the main results. Section 4 concludes.

4.2 The model

The starting point is the model developed in chapter three. I consider two credit market sectors, a banking sector and a bond sector. Small firms rely on bank finance, whereas large firms issue bonds to match the notion of debt specialization of large and small US firms (see Cantillo and Wright, 2000). Banks are modeled as depository institutions, following the setup by Gertler and Karadi (2011). Due to a moral hazard problem between depositors and banks, banks can supply only as much credit to small firms as allowed by their leverage constraint. Mutual funds represent a veil, as in Bernanke et al. (1999). The terms of the optimal bond contract specify the amounts of bonds as well as bond finance premia.

The model economy is populated by the following agents: households, corporate finance firms, intermediate firms, final goods firms, capital goods producers, lending banks and mutual funds. Households consume, supply labor and save via depositing resources with financial intermediaries. Two types of corporate finance firms make financing decisions regarding bank loans and corporate bonds, respectively, in order to finance their investments in physical capital. Intermediate goods sector is monopolistically competitive. These firms combine the physical capital from two sectors with labor to produce differentiated products and set prices. Capital goods firms make investment decisions. Final goods producers combine all the intermediate goods and make it available to households and capital producers in form of consumption and investment goods. The central bank conducts monetary policy by following a Taylor policy rule. The central bank has at its disposal two sector-specific policy instruments to stabilize financial imbalances in the respective credit market. The bank policy instrument is inversely related to the bank lending activity and represents a form of state intervention in the banking sector. The bond policy instrument is a countercyclical tool that affects credit fluctuations in the bond sector. Since the details of the model have been discussed in the third chapter, I present the equilibrium conditions and definitions of respective economic relationships. I also include the changes in relevant equilibrium conditions as a result of bank credit policy or bond macroprudential tool.

The consumption Euler equation and the household labor supply condition take the following forms:

$$\lambda_t = E_t \left\{ \beta R_t \lambda_{t+1} \right\}, \tag{4.1}$$

$$w_t = \frac{\psi_L L_t^{\phi_L}}{\lambda_t}, \tag{4.2}$$

where $\lambda_t \equiv \frac{1}{(C_t - hC_{t-1})} - \frac{\beta h}{(E_t C_{t+1} - hC_t)}$ denotes the Lagrange multiplier. C_t represents real aggregate consumption, L_t labor hours, w_t real wage rate, and R_t the real risk-free gross return between $t-1$ and t from holdings of real one-period government bonds. E_t is the expectational operator conditional on information available at time t. Parameters $0 < \beta < 1$, $0 < h < 1$, $\psi_L, \phi_L > 0$ denote, respectively, the household's discount factor, the external habit formation parameter, the weight on the disutility of labor and the inverse of the labor supply elasticity.

Total capital is the composite of two bundles of sectoral capital, i.e., capital of individual small and large corporate finance firms, K_t^S and K_t^B, respectively, and it is given by:[6]

$$K_t = \left[\eta (K_t^S)^\rho + (1-\eta)(K_t^B)^\rho\right]^{\frac{1}{\rho}}, \tag{4.3}$$

where $\rho > 0$ is the degree of substitutability between the two types of capital and $0 < \eta < 1$ the share of small corporate finance firms. The capital of type j has the following law of motion:

$$K_t^j = \left\{ (1-\delta)\, K_{t-1}^j + \left(1 - f\left(\frac{I_t^j}{I_{t-1}^j}\right)\right) I_t^j \right\}, \tag{4.4}$$

with I_t^j, K_t^j denoting investment and capital of type j, with $j \in (S, B)$. Note that $f\left(\frac{I_t^j}{I_{t-1}^j}\right) = \frac{\xi^j}{2}\left(\frac{I_t^j}{I_{t-1}^j} - 1\right)^2$. Parameter $\xi^j > 0$ and $0 < \delta < 1$ measure the degree of curvature of investment adjustment cost and the depreciation rate, respectively. The equilibrium condition for optimal investment of type j reads:

$$Q_t^j = \frac{1 - \beta E_t \left\{ \Lambda_{t,t+1} f'\left(\frac{I_{t+1}^j}{I_t^j}\right) \frac{{I_{t+1}^j}^2}{{I_t^j}^2} \right\}}{1 - f\left(\frac{I_t^j}{I_{t-1}^j}\right) - f'\left(\frac{I_t^j}{I_{t-1}^j}\right)\frac{I_t^j}{I_{t-1}^j}}, \tag{4.5}$$

with $\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$ denoting the real stochastic discount factor and Q_t^j the real price of capital of type j.

The average gross return on capital in the specific sector is given by:

$$R_{k,t+1}^j = \frac{r_{k,t+1}^j + (1-\delta) Q_{t+1}^j}{Q_t^j}. \tag{4.6}$$

[6]Similar to Verona et al. (2013), in my framework the individual members are identical within each group, i.e., $K_t^{S,a} = \eta K_t^S$ and $K_t^{B,a} = (1-\eta) K_t^B$, whereby $K_t^{S,a}$ and $K_t^{B,a}$ represent the sector-specific bundles of capital. Hence, the total capital can be also written in terms of sectoral capital bundles: $K_t = \left[\eta^{1-\rho}(K_t^{S,a})^\rho + (1-\eta)^{1-\rho}(K_t^{B,a})^\rho\right]^{\frac{1}{\rho}}$.

where $r^j_{k,t}$ denotes the rental price of capital of type j. From the firm's cost minimization problem, the rental price of capital is determined by:

$$r^j_{k,t} = \left[\alpha A_t s_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \left(K^j_t\right)^{\rho-1} K_t^{\frac{1}{\rho}-1}\right]^{\frac{1}{\alpha}}, \tag{4.7}$$

where s_t stands for the average real marginal cost and parameter $0 < \alpha < 1$ is the share of total capital in the production function. The optimality condition for the choice of particular type of capital and labor hours result in:

$$\frac{r^{k,B}_t}{r^{k,S}_t} = \left(\frac{K^B_t}{K^S_t}\right)^{\rho-1}, \tag{4.8}$$

$$w_t = s_t \frac{\alpha Y^m_t}{L_t}. \tag{4.9}$$

The intermediate goods production is determined by:

$$Y^m_t = A_t (K_t)^\alpha L_t^{1-\alpha}, \tag{4.10}$$

where A_t represents aggregate technology.

Equilibrium conditions associated with the optimal choice of price give rise to the New Keynesian Phillips curve with price indexation, expressed in the recursive form using equations:

$$\Pi^*_t = \frac{\epsilon}{\epsilon - 1} \frac{F^m_t}{Z^m_t} \Pi_t, \tag{4.11}$$

where F^m_t and Z^m_t are defined as $F^m_t \equiv Y^m_t s_t + \beta\theta E_t \Lambda_{t,t+1} \Pi^\epsilon_{t+1} \Pi_t^{-\iota\epsilon} F^m_{t+1}$ and $Z^m_t \equiv Y^m_t + \beta\theta E_t \Lambda_{t,t+1} \Pi^{\epsilon-1}_{t+1} \Pi_t^{-\iota(\epsilon-1)} Z^m_{t+1}$. The parameter $0 \leq \iota \leq 1$ measures the degree of price indexation. Parameters $0 < \theta < 1, \epsilon > 0$ denote, respectively, the probability that an intermediate firm cannot adjust its price and the elasticity of substitution between different intermediate goods.

Aggregate output, Y_t, is related to the aggregate intermediate output, Y^m_t, in the following way:

$$Y^m_t = Y_t \Delta_t, \tag{4.12}$$

where Δ_t measures the price dispersion, which is given by:

$$\Delta_t = \theta \Delta_{t-1} \Pi^\epsilon_t \Pi^{-\iota\epsilon}_{t-1} + (1-\theta)^{\frac{-1}{\epsilon-1}} \left(1 - \theta \Pi_t^{\epsilon-1} \Pi_{t-1}^{-\theta(\epsilon-1)}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{4.13}$$

Following Gertler and Karadi (2011), the equilibrium conditions associated with the banking sector specify the marginal gain from expanding bank assets, ν_t, the marginal gain of an additional unit of net worth, η^S_t, the growth rate of bank net worth, $z_{t,t+i}$, and the growth rate of bank capital, $\chi_{t,t+i}$:

$$\begin{aligned}
\nu_t &= E_t \left\{ (1-\gamma^S)\beta\Lambda_{t,t+1}(R^S_{k,t+1} - R_t) + \beta\Lambda_{t,t+1}\gamma^S\chi_{t,t+1}\nu_{t+1} \right\}, &(4.14)\\
\eta^S_t &= E_t \left\{ (1-\gamma^S) + \beta\Lambda_{t,t+1}\gamma^S z_{t,t+1}\eta^S_{t+1} \right\}, &(4.15)\\
z_{t-1,t} &= (R^S_{k,t} - R_{t-1})(1-\tau^S_{t-1})(\phi^S_{t-1}) + R_{t-1}, &(4.16)\\
\chi_{t-1,t} &= \left\{ \frac{\phi^S_t(1-\tau^S_t)}{\phi^S_{t-1}(1-\tau^S_{t-1})} \right\} z_{t-1,t}, &(4.17)
\end{aligned}$$

where $R^S_{k,t} - R_{t-1}$ denotes the bank finance premium. Parameter $0 < \gamma^S < 1$ is the survival probability of bankers. The term $(1-\tau^S_t)\phi^S_t \equiv \frac{(1-\tau^S_t)Q^S_t B^S_t}{N^S_t}$ denotes the average bank leverage ratio and N^S_t bank net worth. The definitions of growth rates are the following: $\chi_{t,t+i} \equiv \frac{Q^S_{t+i}B^S_{p,t+i}}{Q^S_t B^S_{p,t}}$ and $z_{t,t+i} \equiv \frac{N^S_{t+i}}{N^S_t}$. The total value of bank loans of a representative small firm is given by:

$$\begin{aligned}
Q^S_t B^S_t &= Q^S_t B^S_{p,t} + Q^S_t B^S_{g,t},\\
&= Q^S_t B^S_{p,t} + \tau^S_t Q^S_t B^S_t.
\end{aligned}$$

where $Q^S_t B^S_{p,t}$ is the value of loans intermediated by banks and $Q^S_t B^S_{g,t}$ loans intermediated by the central bank. Similar to Gertler and Karadi (2011), the credit policy instrument, τ^S_t, determines the fraction of bank loans intermediated by the policy maker. With the state intervention in place, equations (4.16) and (4.17) are changed in comparison to the third chapter in order to account for bank loans intermediated by the central bank. Any central bank's earnings from the state intervention are transferred to households in the form of lump-sum transfers.

The agency problem gives rise to the leverage constraint of banks:

$$\phi^S_t = \frac{1}{(1-\tau^S_t)} \frac{\eta^S_t}{(\lambda^S_t - \nu_t)}. \tag{4.18}$$

The leverage ratio is increasing for two reasons: the excess value of bank's assets, i.e., loans, ν_t, and additional value from holding another unit of net worth, η^S_t. The leverage ratio declines in λ^S_t, a fraction of funds diverted by bankers. Following Dedola et al. (2013), I assume that λ^S_t is time varying and captures a shock to the confidence in the banking system. Hence, an increase in λ^S_t, implies that depositors can recover less funds from banks. This action leads to the tightening of the leverage constraint and, hence, causes a disruption in bank intermediation, since banks reduce the amount of loans to small firms.

The evolution of bank net worth is given by:

$$N^S_t = \gamma^S[(R^S_{k,t} - R_{t-1})\phi^S_{t-1} + R_{t-1}]N^S_{t-1} + \omega^S(1-\tau^S_{t-1})Q^S_{t-1}B^S_{t-1}. \tag{4.19}$$

Net worth gets accumulated from revenues of bank operations (of surviving bankers) and a start-up transfer from the household, $\omega^S(1-\tau^S_{t-1})Q^S_{t-1}B^S_{t-1}$. Note that the total value of bank loans extended to representative small firms (corporate finance firms) is used to finance their capital purchases:

$$Q^S_t K^S_t = Q^S_t B^S_t. \tag{4.20}$$

The representative firm that relies on bond finance uses her own net worth and bonds to finance capital purchases. Hence, the large corporate finance firm, or for convenience, large firm issues the following amount of bonds:

$$B^B_t = Q^B_t K^B_t - N^B_t.$$

Solving the optimal bond contract,[7] I obtain that the relationship between the return on capital and the bond finance premium is given by:

$$E_t R^B_{k,t+1} = E_t[\rho(\bar{\omega}^B_{t+1})R_t]\exp(\tau^B_t), \tag{4.21}$$

$$\rho(\bar{\omega}^B_{t+1}) = \frac{\Gamma'_t(\bar{\omega}^B_{t+1})}{[(\Gamma_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G_t(\bar{\omega}^B_{t+1}))\Gamma'_t(\bar{\omega}^B_{t+1}) + (1-\Gamma_t(\bar{\omega}^B_{t+1}))(\Gamma'_t(\bar{\omega}^B_{t+1}) - \mu_{t+1}G'_t(\bar{\omega}^B_{t+1}))]} \tag{4.22}$$

where $\rho(\bar{\omega}_{t+1})$ represents the bond finance premium and τ^B_t is the macroprudential policy instrument. The bond policy instrument is an exogenous component of the bond premium, that aims to dampen credit cycles in the bond market. $\Gamma_t(\bar{\omega}^B_{t+1}) \equiv (1-F_t(\bar{\omega}^B_{t+1}))+\int_0^{\bar{\omega}^B_{t+1}} \omega dF_t(\omega^B)$ and $G_t(\bar{\omega}^B_{t+1}) \equiv \int_0^{\bar{\omega}^B_{t+1}} \omega^B dF_t(\omega^B)$. $\Gamma_t(\cdot)$ and $\mu_{t+1}G_t(\cdot)$ denote respectively the share of large firms' earnings received by the mutual fund and the expected monitoring costs. $F_t(\bar{\omega}^B_{t+1})$ is a cumulative distribution function (and the probability of default) of idiosyncratic productivity, ω^B. Similar to Bernanke et al. (1999), I assume that ω^B_t is log normally distributed with $E(\omega^B_t) = 1$ and $Var(\ln\omega^B_t) = \sigma_\omega{}^2$. I allow for monitoring costs to be time-varying in order to model the change in the auditing ability of mutual funds. For example, an unexpected increase in monitoring costs makes the verification of the large firm's project outcomes costlier, i.e., it increases the bond premium.

The zero profit condition of mutual funds is as follows:

$$E_t\left\{[\Gamma_t(\bar{\omega}_{t+1}) - \mu_{t+1}G_t(\bar{\omega}_{t+1})]\frac{Q^B_t K^B_t}{N^B_t}\frac{R^B_{k,t+1}}{R_t}\right\} = \frac{Q^B_t K^B_t}{N^B_t} - 1, \tag{4.23}$$

[7] See, for example, Bernanke et al. (1999).

which can be related to the average leverage ratio of large firms, $\phi_t^B \equiv \frac{Q_t^B B_t^B}{N_t^B}$.

The law of motion for large firms' net worth is given by:

$$N_t^B = \gamma^B (1 - \Gamma_{t-1}(\bar{\omega}_t)) R_{k,t}^B Q_{t-1}^B K_{t-1}^B + W^B, \tag{4.24}$$

where W^B denotes a constant lump-sum transfer of households and parameter $0 < \gamma^B < 1$ determines the fraction of the large firm earnings' share that is accumulated by large firms. Large firms default on bonds if the realization of the idiosyncratic productivity falls below the threshold productivity, which is given by:

$$\bar{\omega}_{t+1} = \frac{Z_t \left(Q_t^B K_t^B - N_t^B \right)}{R_{k,t+1}^B Q_t^B K_t^B}, \tag{4.25}$$

where Z_t denotes the contractual, no-default interest rate on corporate bonds.[8]

The capital rental market and the credit market clear:

$$\int_0^\infty K_{i,t}^S di = K_t^{S,a} = \eta K_t^S, \tag{4.26}$$

$$\int_0^\infty K_{i,t}^S di = K_t^{B,a} = (1-\eta) K_t^B, \tag{4.27}$$

$$B_t^{tot} = B_t^{tot,B} + B_t^{tot,S}, \tag{4.28}$$

where B_t^{tot} represents total credit, $B_t^{tot,S} \equiv \eta Q_t^S B_t^S$ and $B_t^{tot,B} \equiv (1-\eta)(Q_t^B K_t^B - N_t^B)$ total values of bank loans and corporate bonds, respectively. I define the bank loan's share, Υ_t, as the ratio of bank loans between corporate bonds:

$$\Upsilon_t = \frac{B_t^{tot,S}}{B_t^{tot,B}}. \tag{4.29}$$

The aggregate resource constraint is given by:[9]

$$Y_t \quad = \quad C_t + I_t + c\eta \tau_t^S Q_{t-1}^S K_{t-1}^S,$$

where the last term represents resource costs associated with the intervention in the banking sector. Note that the aggregate investment is given by $I_t = \eta I_t^S + (1-\eta) I_t^B$. Parameter c denotes the efficiency costs per unit of central bank's assets, calibrated as in Gertler and Karadi (2011). Note also that the Fisher relation holds:

$$R_t = \frac{R_t^n}{E_t \Pi_{t+1}}, \tag{4.30}$$

[8] The contractual bond interest rate is associated with the threshold productivity, $\bar{\omega}$, i.e., the value of idiosyncratic productivity is such that the large firm's net worth is completely eliminated and the firm is exactly able to pay off the corporate bond.

[9] I assume that the monitoring costs of mutual funds do not deplete the aggregate output and are transferred as a lump sum to households.

where R_t^n denotes the nominal interest rate.

The shocks follow autoregressive processes given by:

$$\ln A_t = \rho_a \ln A_{t-1} + e_{t,A}, \tag{4.31}$$

$$\ln \lambda_t^S = (1-\rho_G)\ln \lambda^S + \rho_G \ln \lambda_{t-1}^S + e_{t,S}, \tag{4.32}$$

$$\mu_t = \frac{1}{1+e^{\Xi_t}}, \tag{4.33}$$

$$\ln \Xi_t = (1-\rho_G)\ln \Xi + \rho_G \ln \Xi_{t-1} + e_{t,B}, \tag{4.34}$$

where $\rho_A, \rho_G \in (0,1)$ and $e_{t,x}, \sim iid(0, \sigma_x^2)$, whereby $x = \{A, S, B\}$. $e_{t,S}$ and $e_{t,B}$ denote, respectively, sectoral shocks in banking and bond sector. The specification of the bond-sector shock ensures that monitoring cost μ_t falls between 0 and 1, as suggested by Fuentes-Albero (2014). Note that I also consider the economy-wide financial shock, which is a combination of two sectoral shocks. λ^S and Ξ represent the steady state values of λ_t^S and Ξ_t.

4.2.1 Welfare measure and policy rules

To assess the welfare implications of policy rules, I specify the welfare measure as the unconditional lifetime household utility:

$$W_t = E\sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{4.35}$$

with the period utility $U(C_t, L_t) \equiv \ln(C_t - hC_{t-1}) - \frac{\psi_L}{1+\phi_L} L_t^{1+\phi_L}$.

Following Lucas (1987, 2003); Faia and Monacelli (2007), I calculate the welfare costs associated with each policy regime. These costs are expressed as the compensation, g, that households would require to remain indifferent between the stochastic economy and the deterministic steady-state environment. This fraction can be determined from the following equation:

$$E\sum_{t=0}^{\infty} \beta^t U(C_t, L_t) = E\sum_{t=0}^{\infty} \beta^t U((1+g)\bar{C}, \bar{L}), \tag{4.36}$$

where $\bar{C}$ and $\bar{L}$ denote the deterministic steady state values of C_t and L_t. The left hand side represents the unconditional expectation of welfare which is obtained using a second-order Taylor approximation, whereas the right hand side is the welfare in the deterministic steady state.[10]

For the welfare comparison of policy regimes, I consider the family of simple interest rules in the form of simple Taylor rules in each policy specification. In the case where the central bank employs a mix of all three instruments I relate two

[10] See further details in appendix C.

credit policy instruments, τ_t^S and τ_t^B, to credit imbalances in the respective credit market. Hence, the specifications of policy rules I compare are given by:

1. Simple Taylor rule :

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)}, \tag{4.37}$$

2. Optimized simple Taylor rule: $\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)}$,

3. Optimized policy combination:
   Optimized simple Taylor rule:

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi(1-\rho_r)},$$

   Bank sector policy instrument:

$$\tau_t^S = \tau^S - \nu_S \ln\left(\frac{B_t^S}{B_{t-1}^S}\right), \tag{4.38}$$

   Bond sector policy instrument:

$$\tau_t^B = \tau^B - \nu_B \ln\left(\frac{B_t^B}{B_{t-1}^B}\right), \tag{4.39}$$

where R^n and Π denote the steady-state values for the nominal interest rate and inflation, R_t^n and Π_t, respectively. The parameter α_π is the weight on inflation, ρ_r measures the degree of interest rate smoothing. Parameters $\nu_S, \nu_B \geq 0$ denote, respectively, the unconventional policy instruments are not used in the steady state and, therefore, the value of both instruments, τ^B and τ^S, is 0. Along the lines of Schmitt-Grohé and Uribe (2007), I consider constrained-optimal rules: For cases 2. and 3., I search for the value of policy coefficient, α_π, and the joint determination of policy coefficients, α_π, ν_S and ν_B, which yields the highest welfare, respectively. In the following, I will explain the modeling of each instrument in more detail.

For the conventional monetary policy, I consider implementable monetary policy rules. Following Schmitt-Grohé and Uribe (2007), these rules ensure the local uniqueness of the rational expectations equilibrium. This implies that the policy coefficient on inflation, α_π, is limited in the interval $[1.01, 3]$ in the context of my model framework. The authors argue that policymakers would have difficulties in communicating the policies associated with larger policy coefficients.

The proposed bank sector policy instrument in equation (4.38) is in the vein of Gertler and Karadi (2011).[11] The central bank intervenes in face of a

[11] The main difference between two specifications of the policy is the relevant financial variable in the bank policy rule. I consider bank credit growth as a relevant indicator, whereas Gertler

freeze/acceleration in bank lending. In the case of a bank credit crunch, the intervention results in additional resources available to small firms relying on bank credit in the form of $\tau_t^S Q_t^S K_t^S$. The amount of the intermediated loans through the central bank are financed by government bonds.

For the bank credit policy, I search for the optimal value of ν_S in the interval of (0,15). The chosen interval is orientated towards the specification by Gertler and Karadi (2011). The authors suggest that the value of ν_S of 10 is a good representation of the magnitude of intervention by the Federal Reserve in the financial crisis of 2008. I do not want to take a stance on the exact number of the policy responsiveness to deviations in the bank credit growth, but rather qualitatively assign that higher values of the policy coefficient should be associated with a more aggressive reaction of the central bank to credit imbalances.

The second credit policy instrument, τ_t^B, aims at stabilizing the bond market by directly affecting the bond premium:

$$E_t R_{k,t+1}^B = E_t[\rho(\bar{\omega}_{t+1}^B) R_t] \exp(\tau_t^B),$$

in the manner specified in equation (4.39). In the presence of changes in bond issuance, the macroprudential instrument reacts to the growth of corporate bonds by altering the finance premium on bonds. This macroprudential tool setup follows Kannan et al. (2012) and Bailliu et al. (2015),[12] who limit the policy coefficient ν_B to the interval of $[0, 1]$. They argue that the value of this policy coefficient is lower than the inflation coefficient since the prime goal of monetary policy is price stability. Furthermore, I study one dimension of macroprudential policy frameworks without specifying the implementation of the macroprudential tool. For example, Quint and Rabanal (2014) suggest that bond premia can be increased by imposing, e.g., additional capital surcharges, whereas the direct provision of liquidity to the bond sector can decrease these premia.

4.3 Results

4.3.1 Calibration

The time unit is one quarter. Most of the parameters are calibrated as in the model by Gertler and Karadi (2011). The parameters related to the financial sector are presented in table 4.1 and justified in the third chapter.

and Karadi (2011) use credit spread in their specification. The reason for a different target is that stabilization effects from the policy related to credit volumes are larger in my framework.

[12]Note that Bailliu et al. (2015) specify the macroprudential tool that reacts to the deviations of credit growth from its steady state value.

Table 4.1: Calibration

Parameter	Value	Description	Target
η	0.263	share of small firms	$\frac{Loans}{Bonds} = 0.66$
γ_S	0.957	survival probability of banker	Leverage: 4
γ_B	0.979	survival probability of large firms	Leverage: 2
λ	0.609	fraction of divertible bank capital	258bp.(annualized)
μ^B	0.079	monitoring cost (mutual funds)	BBB-spread: 209bp.(annualised)
$F(\omega^B)$	0.0134	default probability	SG-debt: 5.37% (annualized)
W^B	0.005	transfer from households	Christiano et al. (2014)
ω^S	0.002	transfer from households	Gertler and Karadi (2011)
ξ^j	1.72	curvature of investment adjustment cost	Gertler and Karadi (2011)
ρ	0.6	substitutability of capital	Verona et al. (2013)

The sources of exogenous variations are non-financial (technology) shocks and financial shocks. Each credit market segment features sector-specific shocks. In particular, I consider an exogenous disturbance to the monitoring ability of mutual funds and bankers' incentive to divert assets. As explained above, the economy-wide financial shock, is a combination of sectoral shocks.

Regarding the calibration of shock processes, I specify the standard deviation of shocks so that the estimated output responses are exactly matched on impact following aggregate supply and financial shocks as in the third chapter. The persistence parameter is set so that the theoretical response of output falls within the estimated credible set. The impulse response matching leads to the following values of parameters: $\rho_A = 0.70$, $\rho_G = 0.70$, $\sigma_A = 0.012$ and $\sigma_S, \sigma_B = 0.067$. For the combined financial shock, the standard deviation is chosen to replicate a rise in both bank and bond premia, in addition to matching the response of output on impact.[13]

[13]The calibrated shock generates a rise in finance premia, that corresponds to the lower bound of the credible set of the estimated financial shock, documented in the chapter three. In order to match the estimated empirical bond spread, I assume that the shock to monitoring costs is five times stronger than the shock to the banking sector.

4.3.2 Welfare implications of economy-wide shocks

Optimal policy rules

Table 4.2 presents policy coefficients under three different policy regimes specified in section 4.2.1. It is important to emphasize that table 4.2 is only supposed to yield a qualitative indication on the combination of policy instruments which is associated with the highest welfare.

Table 4.2: Optimal policy rules

	α_π	ν_S	ν_B	Welfare cost	Relative gain
All shocks					
Simple Taylor rule	1.5	-	-	-0.296	-
Optimized Taylor rule	3.0	-	-	-0.264	0.032
Optimized policy combination	3.0	3	0.2	-0.037	0.259
Technology shocks only					
Simple Taylor rule	1.5	-	-	-0.070	-
Optimized Taylor rule	3.0	-	-	-0.051	0.019
Optimized policy combination	3.0	15	0.3	-0.007	0.063
Financial shocks only					
Simple Taylor rule	1.5	-	-	-0.315	-
Optimized Taylor rule	3.0	-	-	-0.310	0.005
Optimized policy combination	3.0	3	0.2	-0.126	0.189

Notes: In the optimized Taylor rules, the policy parameters α_π are restricted to lie in the interval $[1.01, 3]$, respectively. For non-standard policy rules, I restricted policy parameters ν_S and ν_B to the interval $[0, 15]$ and $[0, 1]$, respectively. All Taylor-type policy rules feature interest rate smoothing with $\rho_r = 0.8$. The welfare cost $g \cdot 100$ is expressed in terms of the steady state consumption (see appendix C). A negative value for welfare costs indicates that households are willing to give up a certain fraction of their steady state consumption in order to remain in the deterministic economy relative to stochastic environment under certain policy regime. The relative gain is calculated as the gain of a specific policy relative to the simple Taylor rule.

The central bank should try to achieve full inflation stabilization in each model version, i.e., $\alpha_\pi = 3.0$. The prescription for the optimal interest rate rule is the same in scenarios with and without uncoventional policies, similar to the conclusions from Cúrdia and Woodford (2011). If additional policy measures are at the central bank's disposal, the central bank should make use of these policy tools.

In the following, I provide some intuition for reaction coefficients of non-standard policy instruments. The use of policy measures has to be balanced against the costs of this activity. Regarding the bank credit policy, costs associated with this policy are rising in the amount of impaired bank loans. Hence, an aggressive reaction of the policy maker in the case of financial shocks is inefficient. Instead a moderate reaction of the central bank results in a sizable amount of loans to small firms. In the case of technology shocks, it is beneficial to exercise the bank policy instrument to the fullest extent, for these actions are not as costly as in the case of financial shocks. Relatively small declines in bank loans in these scenarios (to be shown) are associated with lower costs of the bank credit policy. As for the bond policy instrument, the policy maker uses this instrument with a similar intensity in different shock scenarios. If both shocks are the economy's driving forces, optimal policy coefficients suggest that the stabilization of financial imbalances under financial shock scenarios represents a dominating feature of the policy.

Table 4.2 also represents welfare costs[14] and relative gains of optimized rules compared to the simple Taylor rule.[15] Welfare costs give a fraction of steady-state consumption that households require as a compensation to live in the stochastic economy under a certain policy regime. The relative gain denotes welfare gains of a specific policy over the simple Taylor rule. The first finding is that, the simple Taylor rule yields the highest welfare costs in every shock scenario, whereas the optimal policy mix performs best. Choosing the inflation coefficient in the interest rate policy rule optimally does not considerably improve the performance of a simple Taylor rule. The result regarding the best performance of the optimal policy combination should not come as a surprise, as the central bank can use three policy instruments to achieve macroeconomic stabilization: Interest rate policy aims at attaining inflation stabilization, whereas sectoral policy tool strives to stabilize imbalances in the respective credit market. The second finding is that the largest welfare gains of the optimal policy combination relative to the simple Taylor rule occur in the models in which financial shocks hit the economy. My work confirms the findings of Cúrdia and Woodford (2010), among others, that the benefits of unconventional policy measures are large under extraordinary circumstances, when the process of financial intermediation is severely disrupted. On the other hand, non-financial shocks, such as technology shocks, are associated with limited benefits of the optimal policy mix, e.g., relative gain over the simple Taylor rule yields 0.063% of steady state consumption. Mechanisms at work are discussed below with the help of impulse response functions following respective shocks.

The Ramsey policy

In the following, I compare the performance of three policy regimes against the Ramsey optimal policy. Table 4.3 displays welfare losses of a particular policy compared to the Ramsey policy.[16] The Ramsey planer maximizes household utility subject to the equilibrium conditions of the model economy setting one policy instrument, the nominal interest rate. All three policy rules are inferior to the

[14] See appendix C for details on the calculation of welfare costs.

[15] I do not compare the performance of optimized rules relative to a standard Taylor rule with inflation and output gap since the definition of an output gap is not unambiguous in the context of a New Keynesian model with the endogenous capital accumulation (see, Woodford (2003), Chapter 5).

[16] The Ramsey plan is implemented using Dynare, which runs the package ramsey_policy.

Ramsey policy. Households are willing to sacrifice between 0.133% and 0.292% of their consumption stream to be as well off as under the Ramsey policy. Under the optimal policy mix the welfare costs are reduced twice as much as under Taylor-type rules. Hence, the suggested policy mix is closest to the Ramsey planner's allocation.

Table 4.3: Welfare loss

	α_π	ν_S	ν_B	λ_c
Ramsey policy	-	-	-	-
Simple Taylor rule	1.5	-	-	0.292
Optimized Taylor rule	3.0	-	-	0.255
Optimized policy combination	3.0	3.0	0.2	0.133

Notes: Conditional welfare cost, $\lambda_c \cdot 100$, is defined as a percentage decrease in the Ramsey-optimal consumption process necessary to make the level of welfare under the Ramsey policy identical to the one under the alternative policy (see the details on the calculation of conditional welfare costs in Schmitt-Grohé and Uribe, 2007). The welfare under the Ramsey policy is calculated with the social planner's initial Lagrange multipliers set equal to their steady state values.

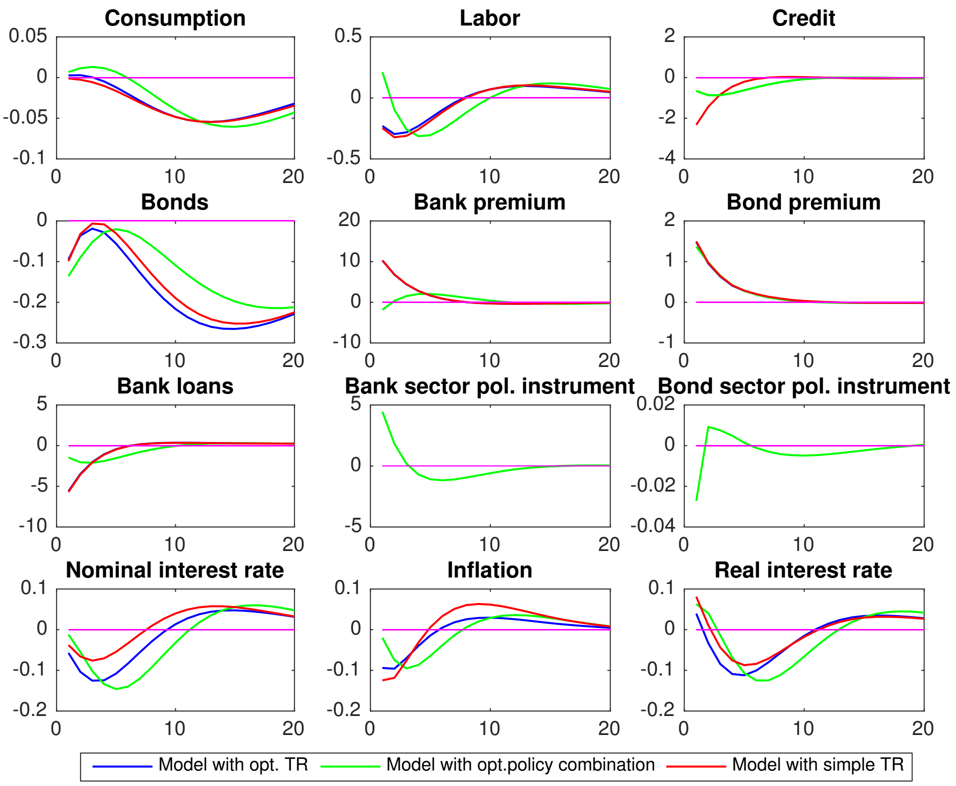
Impulse response functions: Economy-wide financial shocks

As shown in table 4.2, when economy-wide financial shocks are the only source of an economy's business cycle fluctuations, it is optimal for policy makers to use a combination of policy tools. Figure 4.1 displays dynamic responses of main variables to an adverse combined financial shock, causing a confidence loss in banks and increased monitoring costs of mutual funds (by affecting λ_t and μ_t), respectively, under the policies specified in section 4.2.1.

Following the negative financial shock, the functioning of the banking market is more adversely impaired than that of the bond market, which is depicted in a deep bank credit crunch and a substantial increase in bank premia. Due to the increased incentive to divert assets, households do not "trust" banks and reduce deposits, which in turn reduces the ability of banks to lend by tightening their capital constraints. The ensuing deleveraging process of banks induces a recessionary period. In the bond sector, an unexpected increase in monitoring costs of mutual funds raises bond premia, reduces bond volumes and, hence, investments of large firms. As shown in the third chapter, under the simple Taylor rule, there is a change in the corporate debt composition in favor of the less affected credit market segment, the bond market, which dampens the effect of the shock on the real economy.

If the central bank conducts only conventional monetary policy in the form of the Taylor-type interest rate rule, it does not prevent a rise in finance premia and a contraction in credit. For the conventional monetary policy cannot eliminate

Figure 4.1: Adverse financial shock



Note: Green lines refer to the dynamics of the model economy with two sector-specific policy instruments, whereas blue lines refer to the baseline model economy with the Taylor rule. All the interest rates, premia, bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. Horizontal axes display quarters after the shock.

disruptions in credit market segments, it is associated with high welfare costs.[17]

To understand how the optimal policy combination works, I look closer at developments in sectoral credit markets. The bank credit policy stabilizes the main disruption in the financial system associated with the banking market. It helps reduce the degree of financial friction that is intensified through the misbehavior of banks. Namely, the central bank intermediates additional loans to small firms,[18] which enable them to finance their capital purchases. As a consequence, the prices of small firms' capital are moderated, which in turn decreases the return on capital and, therefore, the bank premium. A second effect of the policy is that bank balance sheets improve due to the limited fall in the price of capital, which reduces tightness of bank capital constraints and banks' leverage ratio. Therefore, banks do not reduce

[17]I calculated welfare costs and analyzed the model dynamics for the scenarios without interest rate smoothing. I find that the main model variables behave in a similar manner in the smoothing and non-smoothing model versions.

[18]Initially, the central bank provides additional bank loans, however, as in the following periods bank credit growth accelerates and bank balance sheets improve, the policy tries to dampen the credit cycle. In particular, a negative bank policy instrument means that the central bank goes short in bank loans.

lending to small firms as much as in the case without the bank credit policy. The direct effect of state intervention and the indirect effect on banks' balance sheets temper a decline in small firms' investment and output (not shown). Similarly, the bond macroprudential tool reacts to reduced bond issuance volumes, however, it dampens a rise in bond premia negligibly.[19] Nevertheless, the development in the bond market is smoothed under the bond policy tool, which also moderates capital prices in the bond sector and enhances investment spending of large firms. Overall, due to smaller disruption in the bond market, the use of the bond policy instrument improves only marginally the functioning of this market.

After understanding the economic mechanism behind the non-standard policy instruments, I will provide intuition for their superior welfare performance. The main contribution to economy's stabilization comes from the use of the bank credit policy. This policy alleviates a credit crunch and generates a powerful stimulus to the economy in initial periods. I report a rise in the central bank's balance sheet that corresponds to the total value of 5% of small firms' capital purchases. Hence, the stimulus results in additional investment expenditures for bank finance-dependent firms, which translates into an increase in labor demand and labor productivity (on impact). Since wages are flexible, they will rise to establish an equilibrium in the labor market after the shock hits the economy. As the substitution effect dominates the income effect, households increase labor supply in the scenario with the credit policy. Thus, the model also generates a wealth effect of labor supply (an increase in consumption), which can be one of the reasons behind a better performance of the policy mix relative to the standard Taylor rule. Note that there is a certain degree of consumption smoothing under Taylor-type policies. In these scenarios, a shortfall in the aggregate demand induces a fall in wages and labor hours. Nevertheless, households can rely on the smooth consumption process since they reduce the amount of deposits (e.g., as a result of mistrust in banks). The credit policy restores trust in the banking system, moderating a decline in deposits. In equilibrium, the wealth effect of labor supply dominates the positive effect from the restored confidence in banks, and aggregate consumption increases under the active bank credit policy.

The overall effect of bank and bond policy instruments is the stabilization of respective credit markets, which in turn stabilize aggregate investment and aggregate consumption. By shutting off the bank policy instrument in the counterfactual exercise, the model predicts that the recovery does not feature an overshooting

[19]This instrument operates via balancing the growth in bond volumes. A negative value of the policy instrument indicates that it subdues the bond premium. A positive value of the bond policy instrument (following an improvement in bond issuance volumes) dampens the premium. The value of the bond instrument is low as a result of small changes in bond volumes, which results in hardly visible changes in the bond premium.

effect in the labor market documented above,[20] and welfare benefits are negligible (not reported). Hence, the stabilization of the bond market via the macroprudential instrument is not essential for welfare improvements. This result suggests that the effective policy reaction needs to address the more disrupted credit market segment.

There is a consensus in the literature[21] that the deviation of monetary policy from the standard Taylor rule in form of an additional reaction to financial variables or the use of unconventional policy tools is effective in mitigating adverse effects of financial shocks on the real economy, if these disturbances impair the functioning of financial markets to a large extent. My model featuring a segmented financial market can replicate the results from the aforementioned literature established for one single financial market.

Impulse response functions: Technology shocks

Figure 4.2 gives a visualization of the dynamics of main variables following a negative technology shock under three policy rules, which are associated with quantitatively similar welfare costs in table 4.2. As documented in the New Keynesian model,[22] consumption falls and labor hours increase in the presence of a negative technology shock. The nominal interest rate rises in response to an increase in inflation (as a result of rising marginal costs), which leads to a rise in the real interest rate (since the nominal interest rate moves more than one-to-one with inflation). On the firm side, the adverse technology shock reduces the price of capital goods and, hence, both sectors employ less capital in production (not reported), which induces a fall in sectoral external financing and the total credit volume. Tightening of credit conditions together with the lower value of net worth of banks and firms induces an increase in respective leverage ratios and finance premia.

The qualitative behavior of the main variables is similar under three policy regimes. Strong reaction to inflation deviations in the case of optimized rules (i.e., $\alpha_\pi = 3$) increases relatively more the real interest rate, which in turn induces larger changes in consumption than under the simple Taylor rule. Additionally, the optimized Taylor rule is associated with relatively larger deviations of financial premia and the credit volume from their steady states than the simple rule.[23] However, it reduces inflation volatility, which is welfare-improving. The highest

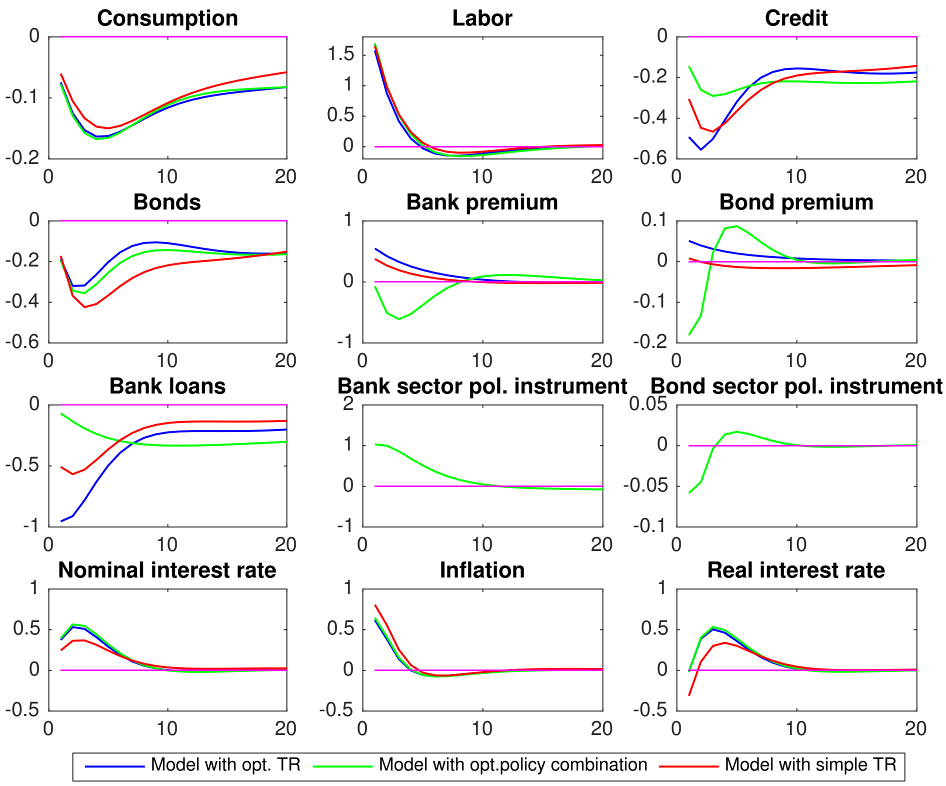
[20] The result regarding the credit policy's stimulus is in line with the model predictions from the aggressive use of credit policy by Gertler and Karadi (2011).

[21] See, for example, Cúrdia and Woodford (2010); Gertler and Karadi (2011); Gertler et al. (2012), among others.

[22] See, for example, Galí and Rabanal (2004); Smets and Wouters (2007).

[23] There is a substitution towards a cheaper form of capital (see figure C.1 in chapter C), provided by the bond sector. Under the simple Taylor rule bond premia turn very low for mutual funds, so that mutual funds are less willing to provide bond financing in comparison to the case with optimized Taylor rule (associated with positive absolute deviation of bond premia from their steady state). This explains differences in bond finance between two model economies using only Taylor policy rule.

Figure 4.2: Adverse technology shock



Note: Green lines refer to the dynamics of the model economy with two sector-specific policy instruments; blue lines refer to the baseline model economy with the optimized Taylor rule and red lines are associated with the simple Taylor rule. All the interest rates, premia, bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. Horizontal axis displays quarters after the shock.

welfare is achieved by the policy mix, which appears to be, like in the case of financial shocks, a result of stabilization of distortions in credit market segments.

Even though the technology shock generates a small propagation effect in the financial market, it is optimal for the policy maker to moderate small imbalances arising in credit market segments. Under the policy mix, bank premia are reduced for a prolonged period of time in order to eliminate a main disruption in the financial system, associated with the banking market. The state intervention reduces the costs of bank finance, fostering capital purchases of small firms and, hence, improving their investment prospects. As long as bank premia are lower than bond premia, firms substitute towards a cheaper form of finance, bank finance (see figure C.1 in appendix C).[24] An additional stabilization effect of the policy mix comes from the bond sector policy instrument. It is cyclical because it counteracts movements in the corporate bond volume: An initial reduction of the bond premium

[24]Exactly the opposite mechanism happens under the (simple/optimized) Taylor rule, where bank finance is more expensive than bond finance. The enhanced reduction of credit under Taylor rules is the product of a rise in financial premia and a precipitous decline in bank loans.

via the macroprudential tool tries to prompt additional lending activity in the market, however, as the bond issuance volume rises in the following periods, the policy instrument increases the bond premium. Despite the cyclicality of the bond macroprudential instrument, it is associated with a smoother development in the bond market, which contributes to credit market stabilization. Furthermore, it affects positively capital goods prices of large firms, improving their investment outcomes. Hence, the total effect of the two non-standard tools is seen in a reduced decline of the total credit volume. The improvement of credit conditions, together with strict inflation stabilization, achieves macroeconomic stabilization, as indicated by welfare costs of 0.007% of steady state consumption in table 4.2.

My results suggest that the use of non-standard policy tools is beneficial in the presence of technology shocks. The literature on this point is divided. For example, Bailliu et al. (2015) show that in their model monetary and macroprudential policy tools have conflicting interests, since the latter aims to stabilize nominal credit growth and, therefore, counteracts the effects of monetary policy. Within the context of my model, both bank and bond policy tool are related to changes in real volumes of bank loans and bonds, respectively. Consequently, they do not conflict explicitly with inflation targeting interest rate rules. On the other hand, Gambacorta and Signoretti (2014) find that the Taylor rule responding to asset prices dampens the propagation of positive technology shock by reducing the expansion of bank balance sheets, their leverage and increasing lending rates. Though my optimized policy mix does not directly respond to asset prices, it tries to attain credit market and inflation stabilization, which in turn results in higher welfare. Cúrdia and Woodford (2010) also address a modified Taylor rule. They find that the rule reacting to the credit spread can be beneficial in the presence of transitory technology shocks, whereas the standard Taylor rule outperforms the augmented Taylor rule if technology shocks are highly persistent.[25] After accounting for highly persistent technology shocks (i.e., $\rho_A = 0.99$ instead of $\rho_A = 0.70$) within my framework, I find that it is still desirable for the central bank to use a combination of monetary, credit and macroprudential policy instruments.

Even though the optimal policy prescribes the use of non-standard policy tools in the presence of technology shocks, central bank lending programs to one credit segment may not be seen as a feasible policy option if this is too costly or not politically implementable. Especially, this argument may be relevant if shocks do not originate directly in financial markets. Furthermore, the bank credit policy alleviates the distortion associated with financial friction in the banking sector, which induces a change in the corporate debt composition towards bank finance. As already explained, this is beneficial within my framework, however, this may cause

[25] Cúrdia and Woodford (2010) show that the modified Taylor rule with credit spread is welfare improving in case of financial shocks and non-financial demand shocks. However, the standard Taylor rule suffices to stabilize the economy in the presence of preference or government shocks.

inefficiencies and moral hazard issues, when financial intermediaries anticipate state intervention and engage in more risk taking (see, e.g., Gertler et al., 2012). In the light of these risks, the policy maker does not make a big mistake by only conducting conventional monetary policy in response to technology shocks. My findings indicate that welfare losses are limited under these policy scenarios.

4.3.3 Sectoral financial shocks

Welfare analysis

In this section I look at the scenarios associated with sector-specific financial shocks, i.e., only one credit market is affected by a financial shock. Table 4.4 presents policy coefficients associated with the optimized and non-optimized policies. I assume that the central bank chooses an optimal policy combination according to equations (4.37), (4.38) and (4.39), knowing exactly the type of shock. Non-optimized policies refer to policy mixes that are not optimal from the point of view of an economy which is only hit by the considered sectoral shock. They are optimal, however, in economies featuring the other type of sectoral shock or combined financial shocks. The relative gain (1) denotes welfare gains of a specific policy over the simple Taylor rule, whereas the relative gain (2) denotes welfare gains of a policy relative to the policy mix, found for the economy hit only by combined financial shocks.

In the case of bank sector shocks,[26] a welfare-maximizing policy combination implies a deviation from strict inflation stabilization ($\alpha_\pi = 1.4$), moderate reaction of the bank credit policy ($\nu_S = 3$) and no use of the bond macroprudential tool ($\nu_B = 0$). Welfare results suggest that the size of the inflation coefficient plays a minor role (c.f., the relative gains (2) of the non-optimized policies with $\alpha_\pi = 3$ and the optimal policy mix with $\alpha_\pi = 1.4$). The optimal policy mix does not feature a bond instrument for following reasons: The unaffected bond market segment features an increase in bond issuance. This has a stabilizing effect on the economy, which contributes to the reduced welfare cost. Hence, inducing a decelerating process of bond issuance, via the bond macroprudential tool, is counterproductive.

[26]The size of the bank sector shock is calibrated so that the response of output on impact matched the empirical counterpart, estimated in the third chapter. This results in higher standard deviation (i.e., $\sigma_S = 0.10$) than the one associated with the combined financial shock.

Table 4.4: Optimal policy rules following sectoral shocks

	α_π	ν_S	ν_B	Welfare cost	Relative gain(1)	Relative gain(2)
Bank sector shocks only						
Optimal policy						
Policy mix	1.4	3	0	0.270	0.424	0.007
Non-optimized policy						
Simple Taylor rule	1.5	-	-	-0.154	-	-0.417
Policy conditional on combined fin.shocks	3.0	3	0.1	0.263	0.417	-
Policy conditional on bond sector shocks	3	4.5	1	0.257	0.411	-0.006
Bond sector shocks only						
Optimal policy						
Policy mix	3	4.5	1	-1.033	0.029	0.005
Non-optimized policy						
Simple Taylor rule	1.5	-	-	-1.062	-	-0.024
Policy conditional on combined fin.shocks	3.0	3	0.1	-1.038	0.024	-
Policy conditional on bank sector shocks	1.4	3	0	-1.064	-0.002	-0.027

Notes: Optimal policy mix refers to the policy combination that is welfare-maximizing in economies with respective sectoral shocks. Non-optimized policies include the simple Taylor rule and policy mixes that the central bank would choose assuming incorrectly the type of shock - combined financial shocks or shocks originating from the non-affected sector. Welfare costs are calculated in the same way as in table 4.2. The relative gain(1) is calculated as the gain of a specific policy relative to the simple Taylor rule, i.e., a difference in welfare costs of the specific policy relative to the simple Taylor rule. The relative gain(2) is calculated as the gain of a specific policy relative to the policy mix, which is the optimal combination of interest rate rule and credit policy instruments in the economy hit by combined financial shock.

Now, I turn to the welfare implications of different policies conditional on bank sector shocks. How large are the mistakes that the central bank commits if she incorrectly identifies the source of the sectoral financial shock? The mistakes are small, if she assumes that economy-wide financial shocks hit the economy and adopts a policy mix that is optimal in the presence of these shocks. Relative gains of the optimal policy response to bank sector shocks over the policy mix (chosen for the case of economy-wide shocks) are 0.007% of steady state consumption. Similarly, if the central bank assumes that shocks originate in the bond sector and uses a policy mix that is optimal in the economy featuring only bond sector shocks, welfare losses are limited.[27] Hence, how important is it that the central bank conducts optimal policy? It is not important, in the context of bank sector shocks, as long as the policy is an optimal response to shocks originating in the bond sector or in both sectors. These results are positive news for policy makers, as they suggest that the policy response does not need to be tailored to shocks emanating in a specific credit market segment. It contradicts a well-known result by Cúrdia and Woodford (2011), who find that the use of optimal policy depends on the nature of the financial disturbance.

How large are mistakes if the central bank does not respond to credit market conditions and conducts conventional monetary policy in the presence of bank sector shocks? The simple Taylor rule results in large welfare costs, equivalent to -0.154% of steady state consumption. On the other hand, the model suggests that households gain from living in the stochastic economy with sectoral bank shocks under policy rules that feature the bank credit policy (e.g., 0.270% of steady state consumption in the case of the optimal policy mix). The economic rationale for the result is the following: Households anticipate that the state intervention will restore trust in the banking sector by providing additional loans (capital) to absorb effects of these shocks. Therefore, the presence of the bank credit policy insures households against risks of the fall in asset prices and depletion of deposits, eliminating their need for precautionary savings. The additional amount of capital and deposits in these scenarios reduce risk perceptions, yielding an increase in the mean consumption in the second order stochastic steady state (which is established using a non-linear moving average toolkit by Lan and Meyer-Gohde, 2013). Hence, the stochastic economy under unconventional policy regimes is preferred over the environment with no credit policy intervention.

Now, I will turn to the discussion of bond sector shocks. The optimal policy response implies that the central bank pursues strict inflation stabilization[28] ($\alpha_\pi =$

[27] The relative gain of the optimal policy mix over the policy mix chosen for economies affected by bond sector shocks is 0.013%, c.f., 0.007%-(-0.006%) = 0.013%. To compute this result, I used two results from relative gains (2) in table 4.4: the relative gain of the optimal policy and the sectoral policy over the policy conditional on economy wide shocks, respectively.

[28] The results suggest that bond sector shocks have inflationary tendencies and, therefore, it is desirable to react strongly to inflation deviations. In the case of bank sector shocks, the opposite

3), uses moderate bank credit policy ($\nu_S = 4.5$), and reacts strongly to imbalances in the bond sector ($\nu_B = 1$). Strict inflation stabilization aims at neutralizing inflationary pressures, whereas the purpose of bank credit policy is to dampen the financial boom in bank loans. The aggressive policy reaction to bond imbalances attempts to address the most disrupted credit market segment and eliminate distortions caused by financial frictions in this sector.

In the following, I will assess welfare implications of policy rules conditional on bond sector shocks. Are central bank's mistakes large if she acts on the assumption that shocks originate in both sectors? The model predicts small relative gains of the optimal policy combination over the policies associated with economy-wide shocks, e.g., 0.005 % of steady state consumption. How important is it that the central bank's policy responds to credit market conditions? The answer is that it is not important within the context of bond sector shocks, because all policy rules have a comparable welfare performance. For example, the relative gain of the optimal policy over the simple Taylor rule is 0.029% of steady state consumption. This result suggests that the optimal policy is ineffective in neutralizing the credit market distortions caused by bond sector shocks. To gain a better understanding of the effects of different policies, I will now turn to the analysis of impulse response functions.

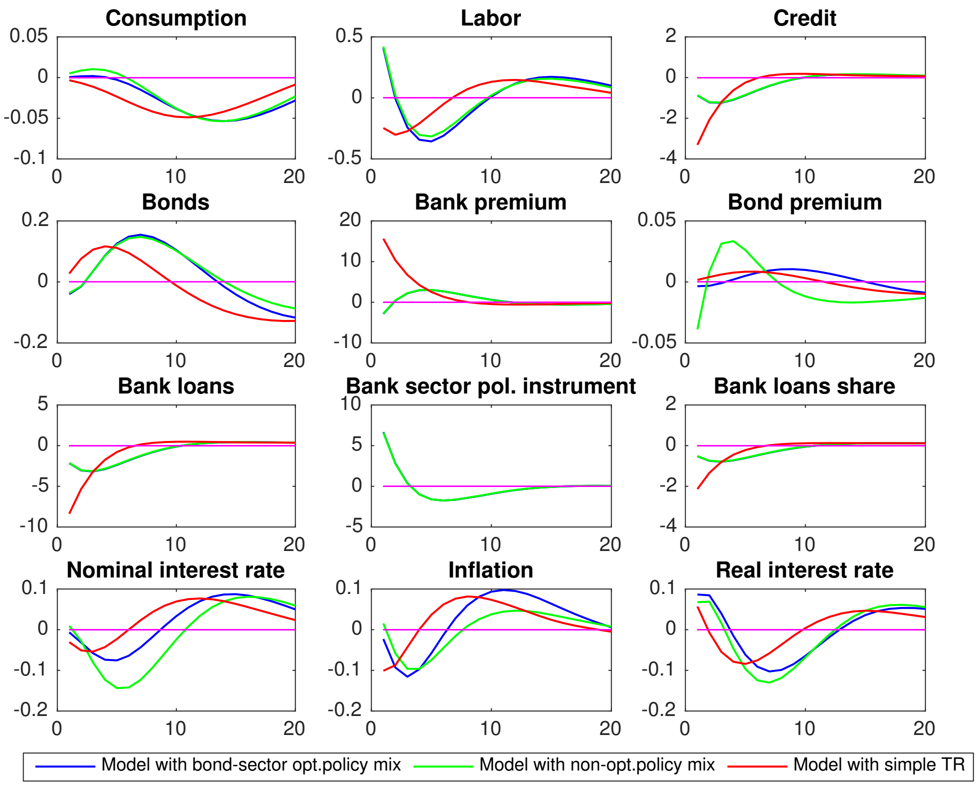
Impulse response analysis

Bank sector shocks: Figure 4.3 presents the responses for an adverse shock to λ_t, causing a loss of confidence in the banking sector. I focus on the model dynamics under the simple Taylor rule, the optimal policy mix and the policy combination, that is chosen optimally by the central bank assuming that financial shocks originate in both sectors.

As the propagation of bank sector shocks resembles the model economy dynamics following economy-wide shocks (in terms of large disruptions in bank lending and a substantial rise in bank premia), the optimized policy in the economy affected by the latter shocks performs well also in the economy with bank sector shocks. The main difference concerns an increase in bond issuance, which intensifies the change in the debt composition in favor of corporate bonds. The substitution towards bond finance, as indicated by a fall in the bank loans' share in figure 4.3, happens because bond premia are lower than bank premia. Higher demand for capital of large firms increases the price of capital of these firms and investment in the bond sector. Under the simple Taylor rule, the change in the corporate debt composition is not sufficient to eliminate the negative effects of the shock, as declines in labor hours and consumption indicate. By actively preventing a bank

is true. As a result of deflationary tendencies, it is optimal to react less aggressively to inflation deviations.

Figure 4.3: Adverse bank sector specific shock

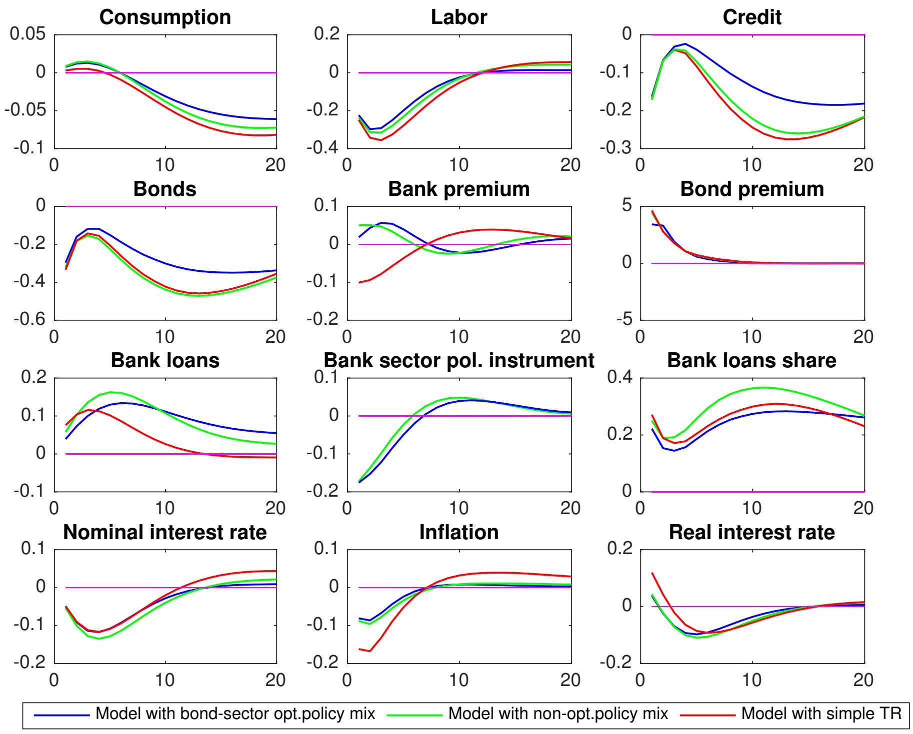


Note: Blue lines refer to the dynamics of model economy with optimal policy mix conditional on bank-sector shocks. Green line refers to model dynamics where the policy maker use a policy mix, which is welfare-maximizing in the economy hit by combined financial shocks. Red line represents the dynamics under the simple Taylor rule. All the interest rates, premia, bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. Horizontal axes display quarters after the shock.

credit crunch, state intervention depresses bank premia, provides additional credit to small firms and stabilizes the severely disrupted bank market. The economic mechanism is described in section 4.3.2.

Bond sector shocks: A contractionary bond sector shock, which increases monitoring costs, rises bond premia and reduces the amount of corporate bonds as well as total credit, as depicted in figure 4.4. Since the banking sector is not affected, there is a substitution towards capital of small firms and bank finance, i.e., an increase in the bank loans' share. As a consequence, this sector features an investment boom, whereby enhanced capital demand drives up capital prices of small firms, reducing bank premia. Even though the banking market manages to absorb partly negative effects of bond-sector shocks, it cannot offset the disruption in the bond market. The reason is that a large portion of firms relies only on bond finance; the financing and investment prospects of these firms remain dismal in the aftermath of the shock. This causes a decline in aggregate investment and real activity.

Figure 4.4: Adverse bond sector shock



Note: Blue lines refer to the dynamics of model economy with optimal policy mix conditional on bank-sector shocks. Green line refers to model dynamics where the policy maker use a policy mix, which is welfare-maximizing in the economy hit by combined financial shocks. Red line represents the dynamics under the simple Taylor rule. All the interest rates, premia, bank and bond policy instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. Horizontal axes display quarters after the shock.

It is interesting to note that bank credit policy tries to counteract a boom in bank lending activity. A negative bank policy instrument indicates that the central bank goes short in intermediating loans. Trying to restrict the bank credit supply,[29] the credit policy induces an increase in bank premia. In my framework, banks benefit from the policy as they earn higher profits from increased premia. They face relaxed leverage constraints as a result of high net worth and the enhanced value of their assets. Therefore, they are willing to intermediate more loans, as presented in figure 4.4.

As indicated by table 4.4, there are quantitatively small differences between the policy mixes and the simple Taylor rule. The optimal use of unconventional policies leads to smoother consumption and labor responses than in the absence of these policies. The bond policy instrument is exercised to the fullest extent, $\nu_B = 1$, however, the resulting depression of bond premia is quantitatively small, i.e., a reduction in the bond premium by one percentage point (on annual basis).

[29]This can be achieved via an additional bank regulation, such as capital surcharges in Basel III (see, e.g., Repullo and Suarez, 2013; Passmore and von Hafften, 2017).

This exerts small effects on the price of investment goods of large firms. As a consequence, bond volumes change little and additional investment expenditures are negligible. These results suggest that there are financial shocks, such as bond sector shocks, where the optimal policy rule cannot eliminate disruptions in the financial system.

4.4 Conclusion

This paper analyzes a combination of interest rate rules and non-standard policy instruments in the context of a medium-scale financial DSGE model with a banking and a bond market segment. If business cycles are driven by financial shocks, which cause severe disruptions in the functioning of both credit market segments, the central bank should use a bank credit policy and a bond macroprudential tool, together with a nominal interest rate, to achieve macroeconomic stabilization. The benefits of these non-standard policy instruments are reduced if shocks have the non-financial nature.

In the context of shocks affecting only the bank sector, my results are promising as they indicate that the policy maker does not make a big mistake if she fails to identify this shock correctly, as long as she acts on the assumption that the shock belongs to the class of financial shocks. The welfare losses are negligible if her policy response is optimally chosen assuming that the economy was buffeted by economy-wide shocks or shocks originating in the bond market.

Conditional on shocks originating in the bond sector, welfare implications of optimal and non-optimal policies are comparable. Within the context of my model, these shocks cause a rise in bond premia, that cannot be accommodated by policy. Hence, the result indicates that some types of financial shocks amplify the distortions, resulting from financial frictions, to such a degree, that an optimal policy response brings minor benefits.

It should be stressed that I assumed that the central bank has the authority to implement all policy instruments. In case of separate monetary and macroprudential authority, one would need to consider the (non-)coordination of two authorities.[30] Using a richer credit market framework, it would be interesting to see if the interests of these authorities are conflicting in the presence of aggregate and sectoral shocks.

[30] See, c.f., Gelain and Ilbas (2017); Carrillo et al. (2017).

Appendix A

Appendix to Chapter 2: A structural empirical analysis of the external finance premium

A.1 SVAR with sign restrictions

Following Uhlig (2005) and Rubio-Ramírez et al. (2010), I consider a VAR model

$$x_t = A + B_{(1)}x_{t-1} + B_{(2)}x_{t-2} + \ldots + B_{(M)}x_{t-M} + u_t,$$

where x_t is a $N \times 1$ vector containing N endogenous variables, A is $N \times 1$ vector of constants, $B_{(i)}$ for $i = 1, ..M$ represents $N \times N$ coefficient matrices and u_t is $N \times 1$ one-step ahead prediction error with a variance-covariance matrix, Σ, of size $N \times N$.
The prediction error is related linearly to the structural shocks:

$$u_t = S\varepsilon_t,$$

whereby S is a non-singular parameter matrix and $\varepsilon_t \sim N(0, I_N)$. A Bayesian estimation is undertaken to obtain the reduced-form VAR.[1] Following Uhlig (2005), both prior and posterior for $(B_{(i)}, \Sigma)$ come from the Normal-Wishart distribution. He shows how the posterior can be analytically obtained.

The procedure can be described as follows. In the first step, the Cholesky identification is used to retrieve the matrix S. In the next step, I use the candidate identifications yielding the identity variance covariance matrix. There exists a nonsingular matrix Q, such that the new impact matrix $S^* = SQ$ and corresponding structural shocks $\varepsilon_t^* = Q^{-1}\varepsilon_t$, whereby reduced-form residuals $u_t = S^*\varepsilon_t^*$. Assuming that Q is an orthogonal matrix, i.e., $Q^{-1} = Q'$, the newly generated structural shocks have an identity variance covariance matrix:

$$E[\varepsilon_t^*\varepsilon_t^*] = E[Q^{-1}\varepsilon_t Q\varepsilon_t'] = Q^{-1}QE[\varepsilon_t\varepsilon_t'] = I_N.$$

Therefore, the candidate structural representations related to each S^* result in different impulse responses:

$$x_t = C(L)S^*\varepsilon_t^*.$$

If the matrices C_i from the reduced-form moving average in equation (A.1) are stacked, the response vector up to the first horizon (on impact) is given by

$$R(1) = E[S' \quad S'C_1']'Q.$$

The sign restrictions related to the specific impulse responses are imposed on the column vectors of the above matrix. The algorithm used to set the sign restrictions is described in Rubio-Ramírez et al. (2010). The functioning of the algorithm can be summarized as follows. I draw a Z matrix such that $Z \sim N(0, I_N)$. Afterwards

[1]Akaike information criterion is used to determine the number of lags.

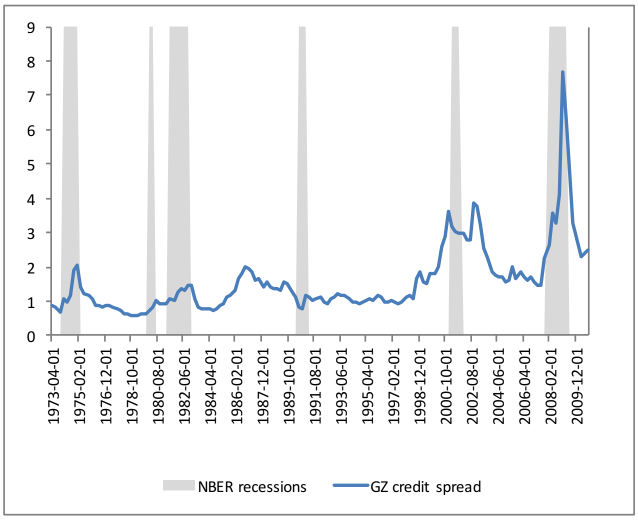
I undertake a QR decomposition of Z. This decomposition enables me to get the orthogonal matrix Q. In the next step, candidate impulse responses are obtained from SQ and $B_{(i)}$ for $i = 1, ..M$. It is checked whether these generated impulse responses satisfy the sign restrictions. If the sign restrictions are not satisfied, a new Z is drawn and an iteration over the same procedure takes place until the sign restrictions are satisfied. The procedure is repeated so many times as necessary as it is to keep 1000 draws that satisfy sign restrictions. The obtained impulse responses are used to compute the statistics as well as to generate the credible sets.

A.1.1 Data and sources

Figure A.1 depicts the measure of the EFP, the GZ credit spread. The spread is constructed by Gilchrist and Zakrajšek (2012) using individual unsecured corporate bond yields of nonfinancial firms.

Data overview:

Figure A.1: Corporate credit spread: GZ credit spread



Notes: The shaded vertical areas represent the NBER-dated recessions. Sample period: 1973Q1-2010Q3. Source:

Real GDP: GDP (seasonally adjusted), divided by GDP deflator. Source: FRED.
GDP deflator Source: FRED.
Nominal short-term interest rate: effective federal funds (FF) rate (secondary market rate), expressed in annual units and in percentage points. Source: FRED.
Credit: sum of corporate bonds, bank loans and other loans and advances (non-financial corporate business) Source: FRED.
GZ credit spread: average credit spread on senior unsecured bonds issued by nonfinancial firms, expressed in annual units and in percentage points. Source: Gilchrist and Zakrajšek (2012).
Stock prices: stock market index, divided by GDP deflator. Source: FRED.

BAA-AAA spread: Moody's Seasoned Baa Corporate Bond Yield -Moody's Seasoned Aaa Corporate Bond Yield, expressed in annual units and in percentage points. Source: FRED.
BAA-10 Tr spread: Moody's Seasoned Baa Corporate Bond Yield (BAA corporate credit index) - 10 year Treasury constant maturity rate, expressed in annual units and in percentage points. Source: FRED.
EBP (excess bond premium): a component of GZ credit spread. Source: Gilchrist and Zakrajšek (2012).

A.2 Overview of theoretical impulse responses

The following tables represent an overview of initial reactions of respective variables following a shock. The reported signs in tables 2.2, 2.3, 2.4, A.1 , A.2 and A.3 related to the responses of respective variables are based on my calculations and results documented in the respective studies. Note that some model codes come from the macroeconomic database by Wieland et al. (2012) and are further extended by myself. All the models except for Gertler and Karadi (2011), Brzoza-Brzezina et al. (2013), Meh and Moran (2010), Cúrdia and Woodford (2010) are estimated. All the shocks represent adverse disturbances. Note that the choice of models differs in the tables because not every financial NK model considers the shock or variable of interest.

Table A.1: Sign restrictions on the price of capital

	Supply	Demand	Monetary	Financial
Carlstrom et al. (2014)	NA	NA	-	-
Christensen and Dib (2008)	-	+	-	NA
Christiano et al. (2010)	-/+	NA	-	-
DeGraeve (2008)	-	-	-	NA
Gerali et al. (2010)	-	-/+	-	-
Gertler and Karadi (2011)	-	NA	-	-
Meh and Moran (2010)	-	NA	-	-
Brzoza-Brzezina et al. (2013)	-	NA	-	-
Brzoza-Brzezina et al. (2013)	+	NA	-	-

Notes: A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; a "0" indicates a zero-response of the variable on impact; "NA" indicates that the model does not consider a specific shock, "+/-" indicates that the impact response can be either positive or negative depending on the type of shock.

Table A.2: Sign restrictions on credit

	Supply	Demand	Monetary	Financial
Carlstrom et al. (2014)	NA	NA	-	-
Christensen and Dib (2008)	-	+	-	NA
Christiano et al. (2010)	0	NA	-	0
Cúrdia and Woodford (2010)	-	+/-	-	-
DeGraeve (2008)	-	+	-	NA
Gerali et al. (2010)	-	-	-	-
Gertler and Karadi (2011)	-	NA	-	-
Meh and Moran (2010)	-	NA	-	-
Brzoza-Brzezina et al. (2013)	-	NA	0	-
Brzoza-Brzezina et al. (2013)	0	NA	-	-

Notes: A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; a "0" indicates a zero-response of the variable on impact; "NA" indicates that the model does not consider a specific shock, "+/-" indicates that the impact response can be either positive or negative depending on the type of shock.

Table A.3: Sign restrictions EFP (extended)

	Supply	Demand	Monetary	Financial
Carlstrom et al. (2014)	NA	NA	-	+
Christensen and Dib (2008)	-	-	+	NA
Christiano et al. (2010)	$-/+^{*}$	NA	+	+
Cúrdia and Woodford (2010)	-	+/-	-/0	+
DeGraeve (2008)	+	-	+	NA
Gerali et al. (2010)	+	-	-	+
Gertler and Karadi (2011)	+	NA	+	+
Meh and Moran (2010)	-	NA	+	+
Brzoza-Brzezina et al. (2013)	-	NA	+	+
Brzoza-Brzezina et al. (2013)	0	NA	0	+

Notes: A "+" indicates that a rise in the EFP on impact, i.e., it is countercyclical; a "-" indicates a fall in the EFP on impact, i.e., it is procyclical; a "0" indicates a zero-response of the EFP on impact; "NA" indicates that the model does not consider a specific shock. *Christiano et al. (2010) report that the premium increases in the model without the Fisher effect.

A.3 Robustness checks

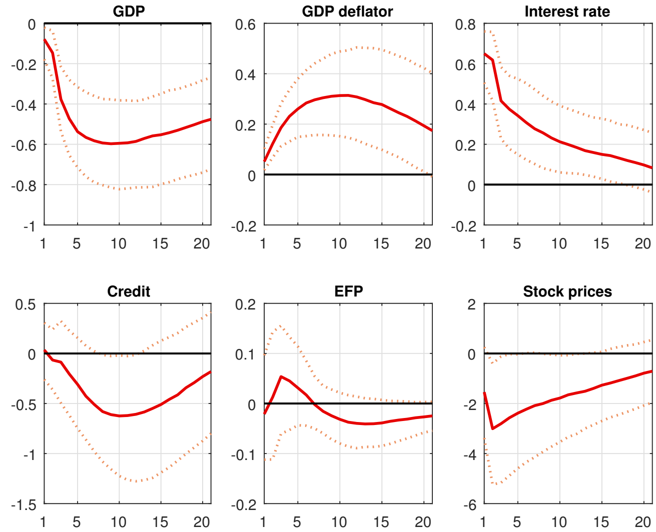
The extended model

Figures A.2, A.3,A.4 and A.5 plot dynamic consequences of endogenous variables following identified supply shocks, demand shocks, monetary policy socks and financial shocks, respectively. Structural shocks are identified using the extended model specified in table 2.5. This identification scheme tries to differentiate between financial and demand shocks in a theory-consistent manner. Structural demand shocks correspond to preference shocks in DSGE models.

The main results regarding the EFP continue to hold. The premium is countercyclical over the short term conditional on the supply shock and the monetary policy shock. It is worth emphasizing that estimated response of the EFP is statistically signification conditional on the latter shock (see figure A.4).

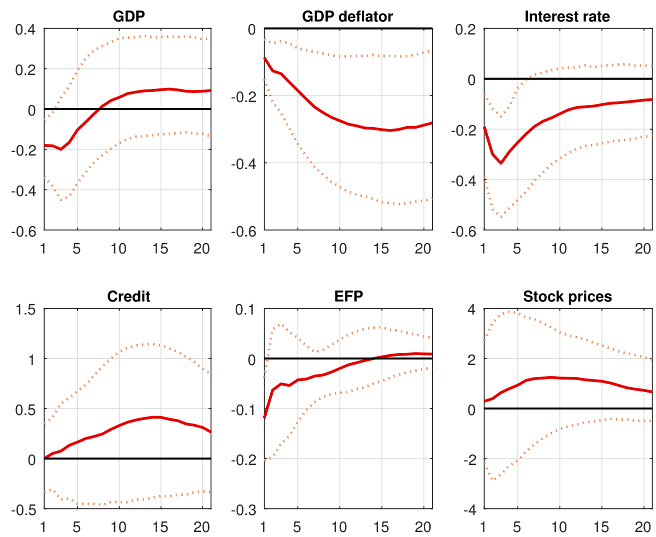
Median impulse response functions of endogenous variables are similar to the ones estimated using the baseline identification approach. By focusing on unrestricted variables, following findings based on median responses can be summarized: Credit and stock prices fall in response to structural supply shocks, which is in line with predictions from DSGE models presented in table A.1 and A.2. Both variables increase following demand shocks, which is consistent with predictions of preference shocks. Following monetary policy shocks, stock prices fall, confirming the conventional wisdom. Namely, all financial frictions models predict a fall in the price of capital, in table A.1. It is also predicted that, conditional on the monetary policy shock, credit declines after a lag, which is consistent with the theory presented in table A.2. With respect to financial shocks, inflation increase, making a case for inflationary nature of financial shocks, which arises in the DSGE model with collateral constraints by Brzoza-Brzezina et al. (2013).

Figure A.2: Extended model: Adverse supply shock



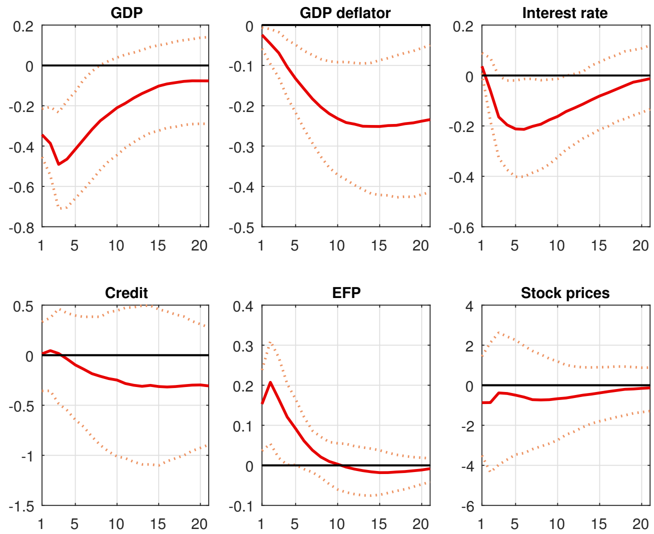
Notes: The bold red lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation aggregate supply shock using identification scheme in table 2.5. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

Figure A.3: Extended model: Adverse demand shock



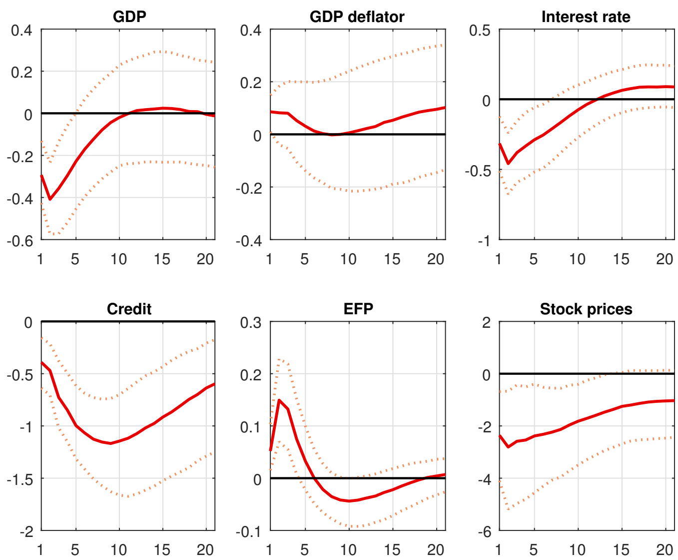
Notes: See notes in figure A.2.

Figure A.4: Extended model: Adverse monetary policy shock



Notes: The bold red lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation aggregate supply shock using identification scheme in table 2.5. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1973Q1-2010Q3.

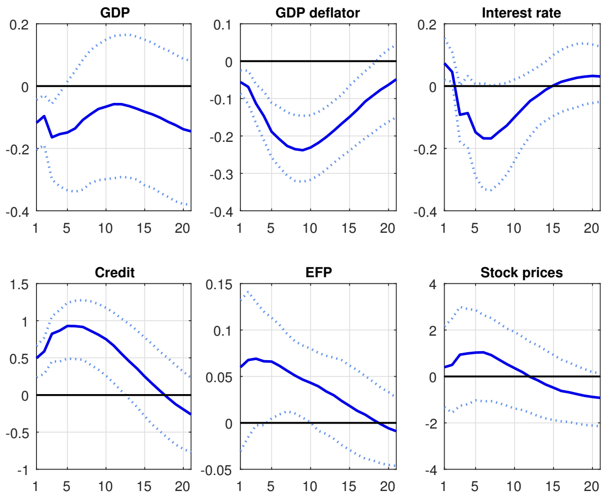
Figure A.5: Extended model: Adverse financial shock



Notes: See notes in figure A.4.

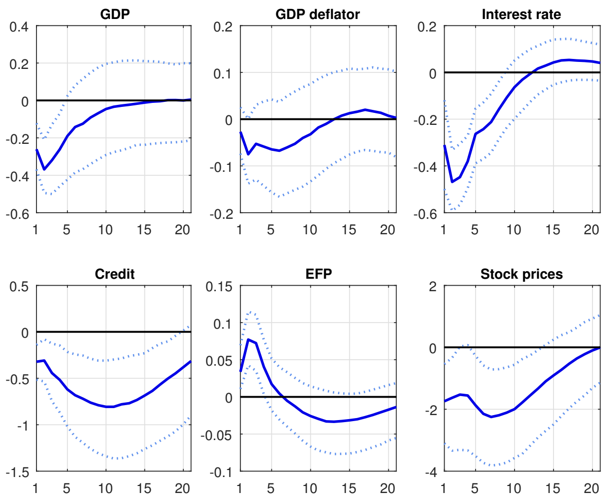
A.3.1 Excluding the Great Recession and the pre-Volcker era

Figure A.6: Robustness check: Adverse monetary policy shock



Notes: The bold lines denote the median of the impulse responses, which are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. The impulse responses are related to an adverse one standard deviation financial shock using identification scheme in table 2.1. GDP, GDP deflator, credit and stock prices are expressed in percentage deviations, whereas the EFP and nominal interest rate are reported in percentage points. The horizontal axis is in quarters. The time period is 1979Q3-2007Q3.

Figure A.7: Robustness check: Adverse financial shock



Notes: See notes in figure 3.6.

Appendix B

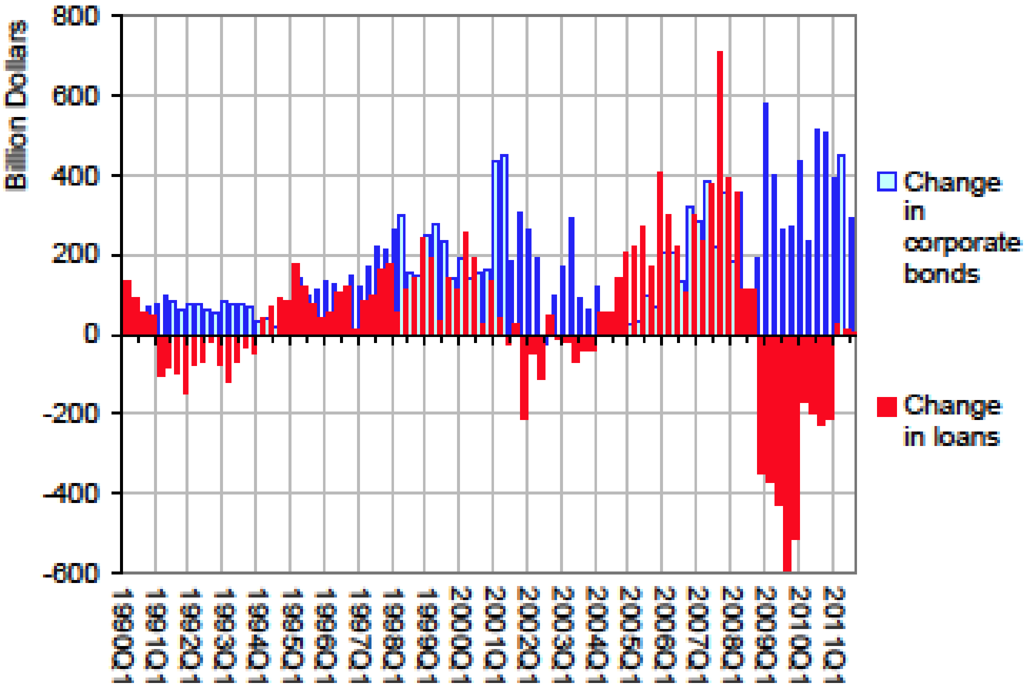
Appendix to Chapter 3: Corporate debt composition and business cycles

B.1 Empirical evidence on the corporate debt composition

B.1.1 Debt financing

Figure B.1 illustrates how bank loans and corporate bonds changed from 1990 to 2011. It shows that recessions are associated with increases in bond issues and declines in bank loans. In the following, I use an SVAR model with sign restrictions to study the conditional dynamics of the corporate debt composition, investment and finance premia.

Figure B.1: Debt financing



Source: Adrian et al. (2012)

B.1.2 Data and sources

Real GDP: GDP (seasonally adjusted), divided by GDP deflator. Source: FRED.
Investment: Business equipment (seasonally adjusted), divided by GDP deflator. Source: FRED.
GDP deflator Source: FRED.
Nominal short-term interest rate: effective federal funds (FF) rate (secondary market rate), expressed in annual units and in percent. Source: FRED.
Credit: sum of corporate bonds, bank loans and other loans and advances

(non-financial corporate business) Source: FRED.
Debt composition (bank loans share): ratio of bank loans to corporate bonds. Source: FRED.
CP-spread: commercial paper rate - FF rate, expressed in annual units and in percent. Source: FRED.
BP-spread: bank prime rate - FF rate, expressed in annual units and in percent. Source: FRED.

B.1.3 SVAR model

Table B.1 summarizes the set of sign restrictions based on major financial New Keynesian models, which corresponds to the extended model in the second chapter. For the purposes of this chapter, I focus on the key variables of interest - the corporate debt composition (the bank loan's share), investment and premia for bank and non-bank finance. It should be noted that the former two variables are left unrestricted. The estimated model results are reported in the section B.3.

Table B.1: Identification of the SVAR model

	Supply	Demand	Financial
Real GDP	-	-	-
Investment	NA	NA	NA
GDP deflator	+	-	NA
Nominal interest rate	+	-	-
Credit	NA	NA	-
Debt composition	NA	NA	NA
EFP	NA	-	+

Notes: A "+" indicates that the impact response is positive; a "-" indicates that the impact response is negative; "NA" a impulse response can be either positive or negative. EFP denotes external finance premium. All the shocks represent adverse disturbances.

B.2 Equilibrium conditions

Households

$$\lambda_t = E_t \left\{ \beta R_t \lambda_{t+1} \right\} \tag{B.1}$$

$$w_t = \frac{\psi_L \, L_t^{\phi_L}}{\lambda_t} \tag{B.2}$$

$$\lambda_t = \frac{1}{(C_t - hC_{t-1})} - \frac{\beta h}{(E_t C_{t+1} - hC_t)} \tag{B.3}$$

$$\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t} \tag{B.4}$$

Intermediate goods producers

$$Y_t^m = A_t(K_t)^\alpha L_t^{1-\alpha}\Delta_t \tag{B.5}$$

$$K_{t-1} = \left[\eta(K_t^S)^\rho + (1-\eta)(K_t^B)^\rho\right]^{\frac{1}{\rho}} \tag{B.6}$$

$$r_{k,t}^j = \left[\alpha A_t s_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \left(K_t^j\right)^{\rho-1} K_t^{\frac{1}{\rho}-1}\right]^{\frac{1}{\alpha}} \tag{B.7}$$

$$\frac{r_t^{k,B}}{r_t^{k,S}} = \left(\frac{K_t^B}{K_t^S}\right)^{\rho-1} \tag{B.8}$$

$$w_t = s_t \frac{\alpha Y_t^m}{L_t} \tag{B.9}$$

$$Y_t^I = Y_t \Delta_t \tag{B.10}$$

$$\Pi_t^* = \frac{\epsilon}{\epsilon-1}\frac{F_t^m}{Z_t^m}\Pi_t, \tag{B.11}$$

$$F_t^m = Y_t^m s_t + \beta\theta E_t \Lambda_{t,t+1}\Pi_{t+1}^{\epsilon}\Pi_t^{-\iota\epsilon}F_{t+1}^m \tag{B.12}$$

$$Z_t^m = Y_t^m + \beta\theta E_t \Lambda_{t,t+1}\Pi_{t+1}^{\epsilon-1}\Pi_t^{-\iota(\epsilon-1)}Z_{t+1}^m \tag{B.13}$$

$$\Delta_t = \theta\Delta_{t-1}\Pi_t^{\epsilon}\Pi_{t-1}^{-\iota\epsilon} + (1-\theta)^{\frac{-1}{\epsilon-1}}\left(1-\theta\Pi_t^{\epsilon-1}\Pi_{t-1}^{-\theta(\epsilon-1)}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.14}$$

Capital good producers

$$Q_t^j = \frac{1-\beta E_t\left\{\mathit{\Lambda}_{t,t+1} f'\left(\frac{I_{t+1}^j}{I_t^j}\right)\frac{{I_{t+1}^j}^2}{{I_t^j}^2}\right\}}{1-f\left(\frac{I_t^j}{I_{t-1}^j}\right) - f'\left(\frac{I_t^j}{I_{t-1}^j}\right)\frac{I_t^j}{I_{t-1}^j}} \tag{B.15}$$

$$K_t^j = \left\{(1-\delta)\,K_{t-1}^j + \left(1-f\left(\frac{I_t^j}{I_{t-1}^j}\right)\right)I_t^j\right\} \tag{B.16}$$

Banks and small firms:

$$\nu_t = E_t\left\{(1-\gamma^S)\beta\Lambda_{t,t+1}(R_{k,t+1}^S - R_t) + \beta\Lambda_{t,t+1}\gamma^S\chi_{t,t+1}\nu_{t+1}\right\} \tag{B.17}$$

$$\eta_t = E_t\left\{(1-\gamma^S) + \beta\Lambda_{t,t+1}\gamma^S z_{t,t+1}\eta_{t+1}\right\} \tag{B.18}$$

$$z_{t-1,t} = (R_{k,t}^S - R_{t-1})(\phi_{t-1}^S) + R_{t-1} \tag{B.19}$$

$$\chi_{t-1,t} = \left(\frac{\phi_t^S}{\phi_{t-1}^S}\right) z_{t-1,t} \tag{B.20}$$

$$Q_t^S K_t^S = N_t + D_t \tag{B.21}$$

$$\phi_t^S \equiv \frac{Q_t^S K_t^S}{N_t^S} = \frac{\eta_t}{(\lambda_t^S - \nu_t)} \tag{B.22}$$

$$N_t^S = \gamma^S[(R_{k,t}^S - R_{t-1})\phi_{t-1}^S + R_t]N_{t-1}^S + \omega^S Q_t^S K_{t-1}^S \tag{B.23}$$

$$R_{k,t+1}^S = \frac{r_{k,t+1}^S + (1-\delta)Q_{t+1}^S}{Q_t^S} \tag{B.24}$$

Mutual funds and large firms

$$B_t^B = Q_t^B K_t^B - N_t^B \tag{B.25}$$

$$E_t R_{k,t+1}^B = E_t[\rho(\bar{\omega}_{t+1}^B) R_t] \tag{B.26}$$

$$\rho(\bar{\omega}_{t+1}^B) = \frac{\Gamma_t'(\bar{\omega}_{t+1}^B)}{[(\Gamma_t(\bar{\omega}_{t+1}^B) - \mu_{t+1} G_t(\bar{\omega}_{t+1}^B))\Gamma_t'(\bar{\omega}_{t+1}^B) + (1 - \Gamma_t(\bar{\omega}_{t+1}^B))(\Gamma_t'(\bar{\omega}_{t+1}^B) - \mu_{t+1} G_t'(\bar{\omega}_{t+1}^B))]} \tag{B.27}$$

$$\Gamma_t(\bar{\omega}_{t+1}^B) = (1 - F_t(\bar{\omega}_{t+1}^B)\bar{\omega}_{t+1}^B + \int_0^{\bar{\omega}_{t+1}^B} \omega dF_t(\omega^B) \tag{B.28}$$

$$F_t = \Phi\left(\frac{\ln(\omega_t^B) + \frac{\sigma_{\omega,t}}{2}}{\sigma_{\omega,t}}\right) \tag{B.29}$$

$$f_t = \frac{1}{\sqrt{2\pi}\omega_t^B \sigma_{\omega,t}} \exp\left[-\frac{1}{2}\left(\frac{\ln(\omega_t^B) + \sigma_{\omega,t}^2}{\sigma_{\omega,t}}\right)^2\right] \tag{B.30}$$

$$\Gamma_t = \Phi\left[\left(\frac{\ln(\omega_t^B) + {\sigma_{\omega,t}}^2}{\sigma_{\omega,t}^2}\right) - \sigma_{\omega,t}\right] + \omega_t^B \left\{1 - \Phi\left[\left(\frac{\ln(\omega_t^B) + {\sigma_{\omega,t}}^2}{\sigma_{\omega,t}}\right)\right]\right\} \tag{B.31}$$

$$G_t = \Phi\left[\left(\frac{\ln(\omega_t^B) + \sigma_{\omega,t}^2}{\sigma_{\omega,t}}\right) - \sigma_{\omega,t}\right] \tag{B.32}$$

$$F_t' = 1 - F_t \tag{B.33}$$

$$G_t' = \omega_t^B \frac{1}{\sqrt{2\pi}\omega_t^B \sigma_{\omega,t}} \exp\left[-\frac{1}{2}\left(\frac{\ln(\omega_t^B) + \sigma_{\omega,t}^2}{\sigma_{\omega,t}}\right)\right] \tag{B.34}$$

$$\bar{\omega}_{t+1} = \frac{Z_t\left(Q_t^B K_t^B - N_t^B\right)}{R_{k,t+1}^B Q_t^B K_t^B} \tag{B.35}$$

$$N_t^B = \gamma^B (1 - \Gamma_{t-1}(\bar{\omega}_t)) R_{k,t}^B Q_{t-1}^B K_{t-1}^B + W^B \tag{B.36}$$

$$\phi_t^B \equiv \frac{Q_t^B B_t^B}{N_t^B} \tag{B.37}$$

Market clearing and some definitions

$$Y_t = C_t + I_t \tag{B.38}$$

$$I_t = \eta I_t^S + (1 - \eta) I_t^B \tag{B.39}$$

$$\int_0^\infty K_{i,t}^S di = K_t^{S,a} = \eta K_t^S, \tag{B.40}$$

$$\int_0^\infty K_{i,t}^S di = K_t^{B,a} = (1 - \eta) K_t^B, \tag{B.41}$$

$$B_t^{tot} = (1 - \eta)(Q_t^B K_t^B - N_t^B) + \eta Q_t^S B_t^S, \tag{B.42}$$

$$\Upsilon_t = \frac{\eta Q_t^S B_t^S}{(1 - \eta)(Q_t^B K_t^B - N_t^B)}. \tag{B.43}$$

Shock processes

$$\ln A_t = \rho_a \ln A_{t-1} + e_{t,A}, \tag{B.44}$$

$$\ln \lambda_t^S = (1-\rho_G)\ln \lambda^S + \rho_G \ln \lambda_{t-1}^S + e_{t,S}, \tag{B.45}$$

$$\mu_t = \frac{1}{1+e^{\Xi_t}} \tag{B.46}$$

$$\ln \Xi_t = (1-\rho_G)\ln \Xi + \rho_G \ln \Xi_{t-1} + e_{t,B}, \tag{B.47}$$

Monetary policy

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_r} \left(\left(\frac{\Pi_t}{\Pi}\right)^{\alpha_\pi}\right)^{1-\rho_r}, \tag{B.48}$$

$$R_t = \frac{R_t^n}{E_t \Pi_{t+1}}. \tag{B.49}$$

B.3 Impulse response functions: SVAR and DSGE model

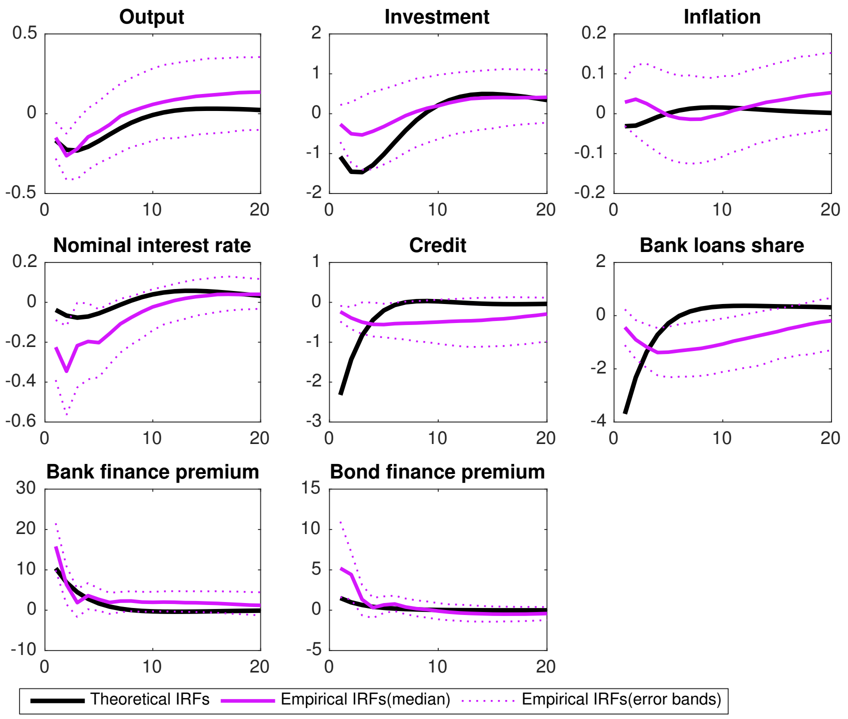
Figures B.2 and B.3 depict the estimated median impulses responses together with the respective credible sets. The median impulse responses are estimated from a Bayesian VAR with 1000 draws. The bounds are the 16th and 84th percentiles. To compare the theoretical and empirical impulse responses, I chose the size of financial shock so that the output response on impact is matched. Figure B.2 shows that the theoretical model does pretty well in matching the persistence and shape of empirical impulse responses. Most of the impulse responses fall into 68% percent posterior probability regions of the estimated impulse responses.

The negative reaction of investment is more cyclical in the model than in the data. The impulse response of the bank loans' share reacts stronger than the empirical counterpart throughout the period considered. It should be emphasized that the bank loan share was unrestricted in the SVAR. These key results suggest that the predictions from my benchmark model are in line with the empirical effects of the financial shock.

Interestingly, similar to the SVAR evidence, the DSGE model predicts a fast recovery of the banking sector. The reason is that banks can rather quickly restore their profitability by charging high loan premia. As a consequence, banks stabilize their balance sheet positions and start extending loans to firms. Once the banks are capitalized, they intermediate loans that the small firm sector uses for financing capital purchases.

The dynamic consequences of estimated financial shock are in line with predic-

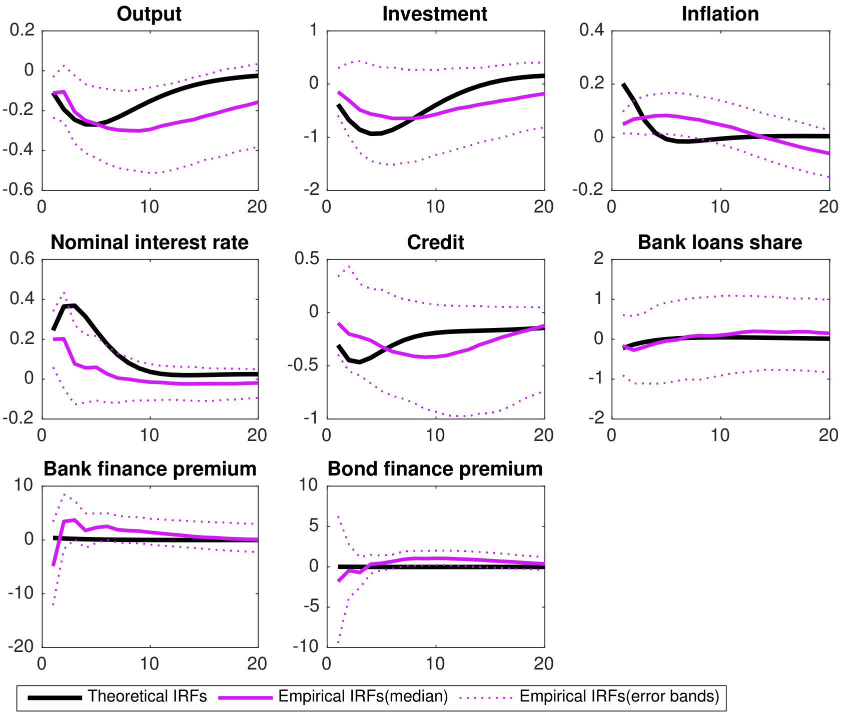
Figure B.2: Adverse financial shock



Blue lines refer to the impulse responses generated by the benchmark theoretical model following the combined financial shock. Magenta lines refer to the estimated financial shock (bank spread shock) from the SVAR model. The identification is specified in table B.1. The error bands represent 16% and 84% percentile of posterior distribution. The time period is 1980Q1-2014Q2. Finance premia, nominal interest rate and the bank loan's share are reported in absolute deviations, the remaining variables are expressed in percentage deviations. The horizontal axis displays quarters after shock.

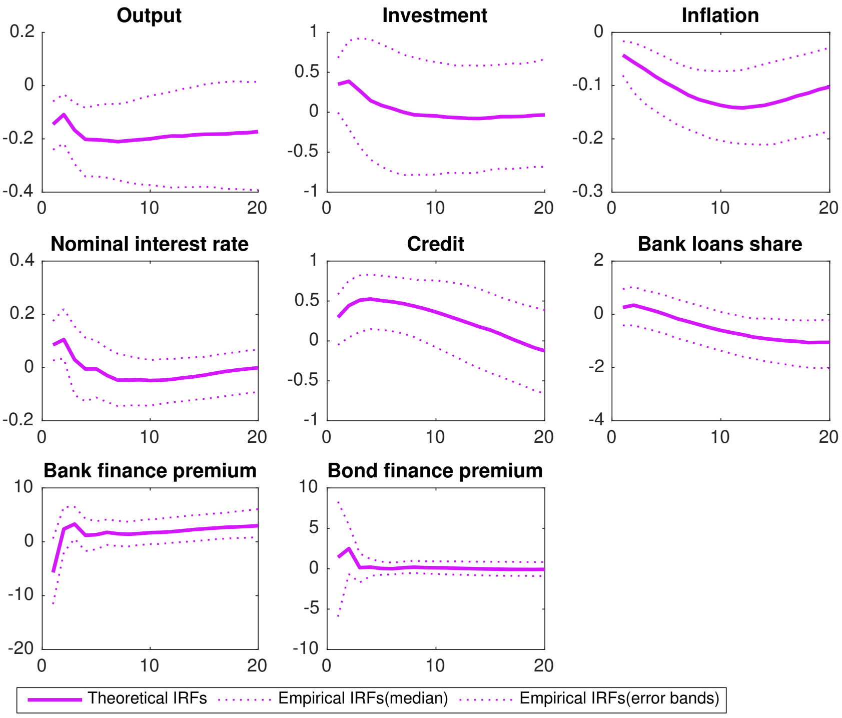
tions of DSGE models, for example, Gertler and Karadi (2011), Bernanke et al. (1999), Christiano et al. (2010) to name a few. The novel feature of the model refers to the dynamics of the corporate debt composition. The decline in the ratio of bank loans to corporate bonds is statistically significant. Two measures of finance premia for the short-term bank and non-bank corporate debt are statistically significant as well. The spread on the bank loans seem to increase substantially more than the spread on non-bank debt. For completeness, I also include the estimated impulse responses to the aggregate demand shock.

Figure B.3: Adverse supply shock



Black lines refer to the impulse responses generated by the benchmark theoretical model following the technology shock. Magenta lines refer to the estimated aggregate supply shock from the SVAR model. The identification is specified in table B.1. The error bands represent 16% and 84% percentile of posterior distribution. The time period is 1980Q1-2014Q2. Finance premia, nominal interest rate and the bank loan's share are reported in absolute deviations, the remaining variables are expressed in percentage deviations. The horizontal axis displays quarters after shock.

Figure B.4: Adverse demand shock



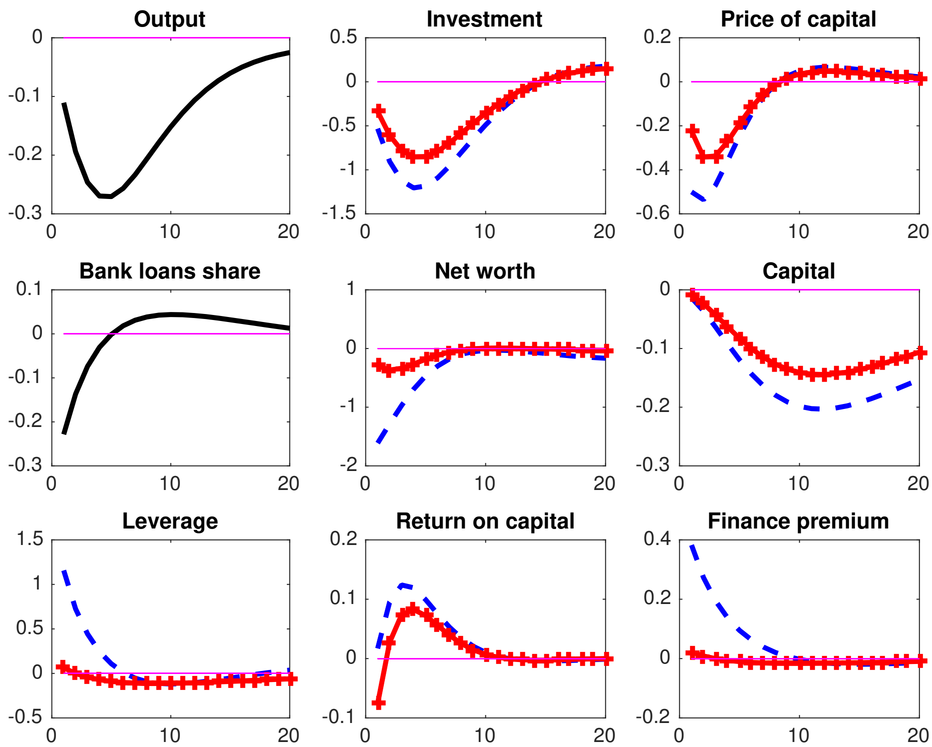
Notes: See notes in figure B.3.

B.4 Extended impulse response analysis

B.4.1 Technology shocks

Figure B.5 depicts the responses of some key variables in the model following a negative technology shock in the benchmark economy. A decrease in aggregate TFP leads to a strong and persistent decrease in investment. Note that the propagation of a technology shock with respect to investment matches well the empirical evidence on the supply shock (c.f., figure B.3).

Figure B.5: Adverse technology shock



Note: Blue dashed lines refer to the variables associated with the banking sector, whereas the red circled lines refer to the bond sector. Black lines refer to the aggregates. Finance premia and the bank loan's share are reported in absolute deviations, the remaining variables are expressed in percentage deviations.

The technology shock has negligible effects on the financial variables (small changes in premia and debt composition). Initially, bank loans do not change as much as bonds which results in an increase in the loan-to-bond financing ratio. However, the banking sector is affected more by the shock since it is more leveraged. Declines in asset prices reduce the value of the bank's net worth which makes bank finance premia rise and lead to a further tightening of loan supply.

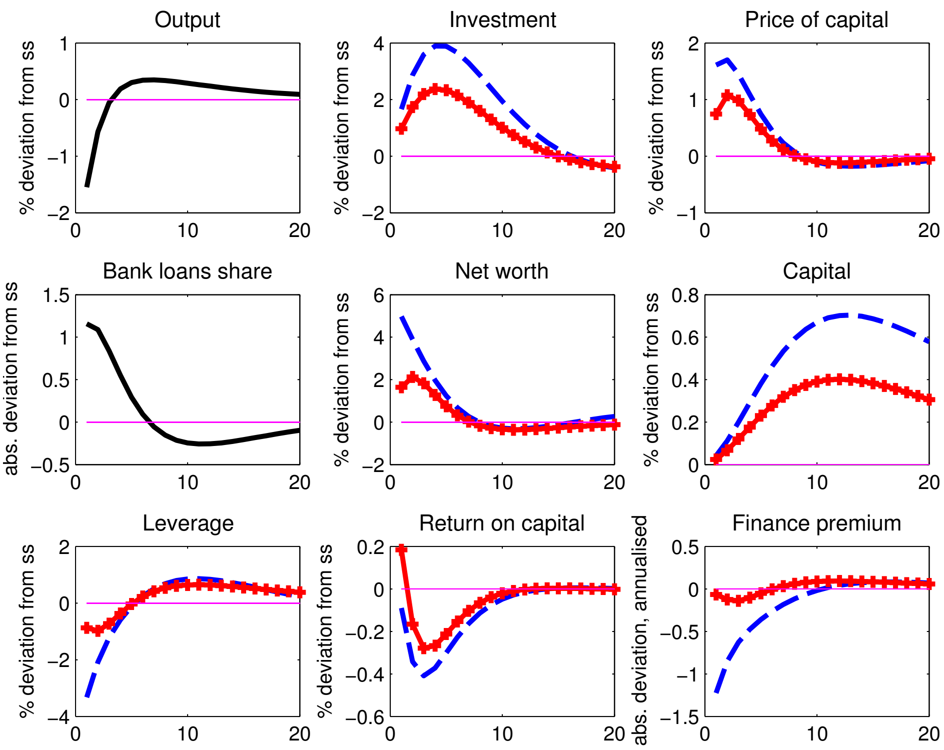
B.4.2 Preference shocks

One possible theoretical model extension is to consider demand shocks. I introduce a shock to preferences as proposed by Smets and Wouters (2003). More precisely, I assume that the stochastic discount factor of households is time-varying:

$$\ln \beta_t = (1 - \rho_\beta) \ln \beta + \rho_\beta \ln \beta_{t-1} + e_{t,\beta},$$

where $\rho_\beta \in (0, 1)$ and $e_{t,\beta} \sim iid(0, 1)$.

Figure B.6: Stochastic discount factor shock



Note: Blue dashed lines refer to the variables associated with the banking sector, whereas the red circled lines refer to the bond sector. Black lines refer to the aggregates. Finance premia and the bank loan's share are reported in absolute deviations, the remaining variables are expressed in percentage deviations.

The shock reduces consumption (not shown) and output and leads to the crowding-in of investment. The investment boom is caused by a decline in capital prices and finance premia. Given the good balance sheet positions of banks, they extend credit to small firms, causing the ratio of bank loans to bonds to increase initially. Over the medium term, the model reproduces a change in the bank loan share similar to the one in the empirical model. Note that the declines in finance premia match my empirical evidence on demand shocks.

Appendix C

Appendix to Chapter 4: An optimal policy mix for segmented credit markets

C.1 Welfare

The welfare measure is given by the lifetime household utility:

$$\text{Welfare} = \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{C.1}$$

with the period utility $U(C_t, L_t) \equiv \left(\ln(C_t - hC_{t-1}) - \frac{\psi_L}{1+\phi_L} L_t^{1+\phi_L}\right)$. To compute the unconditional welfare measure, I take the unconditional expectation of lifetime utility:

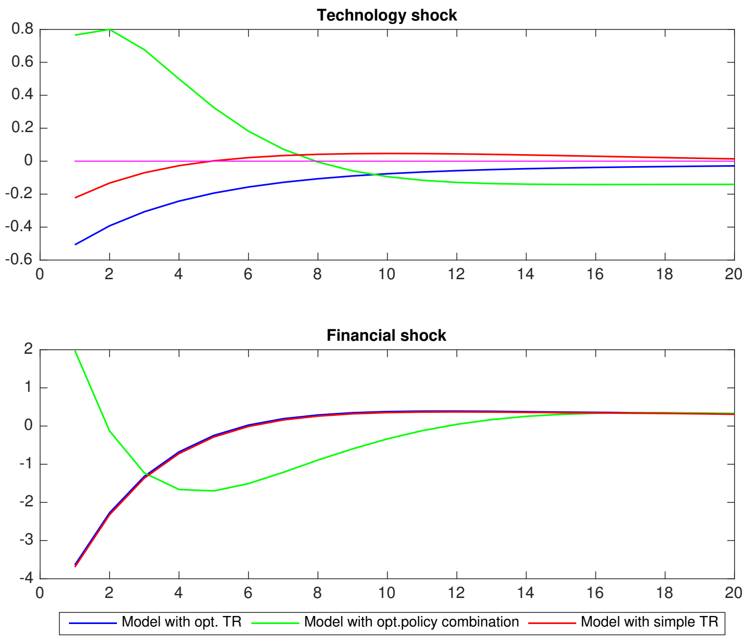
$$\begin{aligned} E[\text{Welfare}] &= E \sum_{t=0}^{\infty} \beta^t U((1+g)\bar{C}, \bar{L}) \\ &= \frac{1}{1-\beta} \left(\ln((1+g)(1-h)\bar{C}) - \frac{\psi_L}{1+\phi_L} \bar{L}^{1+\phi_L} \right) \end{aligned}$$

where g denotes a fraction of steady-state consumption that makes agents in the non-stochastic economy as well off as in the stochastic economy. The term $\frac{g \cdot 100}{\bar{C}}$ represents welfare costs reported in table 4.2 and 4.4. I solve for g, by equating the unconditional welfare in the deterministic steady state and in the stochastic environment, as specified in equation C.1 . The latter welfare measure is computed via the second order approximation of the model. A negative value of g indicates that households are willing to give up a certain fraction of permanent consumption in order to remain in the non-stochastic steady state relative to stochastic equilibrium under certain policy regime. Or equivalently, negative welfare cost represents a percentage decrease in steady state consumption necessary to make household indifferent between the deterministic and stochastic environment.

C.2 Impulse responses: Corporate debt composition

Figure C.1 depicts the reaction of the bank loans' share, i.e., the measure of corporate debt composition to aggregate shocks. Under simple Taylor rules, the composition changes in favour of corporate bonds, as bond finance is less expensive source of finance. The shift reverse in the presence of the bank credit policy. The reason is that state intervention depresses bank premia, making bank finance cheaper. Hence, the shift is reversed towards capital of small firms and bank finance is illustrated in the increase in the bank loan share.

Figure C.1: Bank loan share



Note: Green lines refer to the dynamics of the model economy with two sector-specific policy instruments, whereas blue lines refer to the baseline model economy with the Taylor rule. The bank loans' share instruments are reported in absolute deviations from the steady state, in percentage points. The remaining variables are reported in percentage deviations from the steady state. Horizontal axes display quarters after the shock.

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Jelena Živanović